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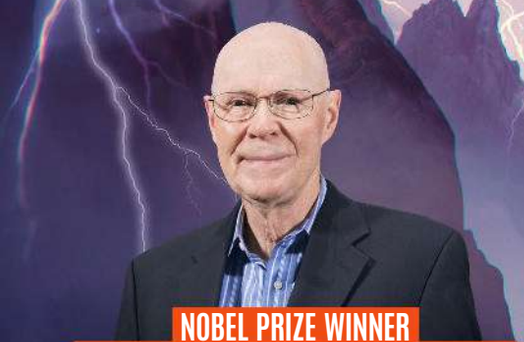
ALL ABOUT SPACE

ISSUE 133
SEPTEMBER 2022

ALIEN STORMS

INCREDIBLE WEATHER ON OTHER WORLDS
IS OUR SUN BECOMING MORE DEADLY?
WHAT CAUSES THEM?

20 MIND-BLOWING UNIVERSE FACTS



NOBEL PRIZE WINNER
"IN MY DAY, THE BIG BANG WASN'T ACCEPTED"

NASA'S MARS RECONNAISSANCE ORBITER / LATEST SPACE NEWS
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FUTURE
ISSUE 133

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WELCOME

ISSUE 133

We're heading into late summer, and that means many of you will be looking to dust off your observing equipment to embrace the longer, darker evenings. Some of you may be looking to buy a new telescope or accessories, and that's where our guide to astronomy on a budget is here to help. From making sure you make the right choice on your next piece of kit – whether it's picking binoculars or eyepieces – to our top picks of instruments under £500, we've got you covered.

This month, we explore the space weather in our Solar System, including the angry outbursts from the Sun and the polar vortex swirling in the atmosphere of Saturn. If you're looking to brush up on your knowledge of the cosmos (or need some inspiration for a pop quiz!), turn to page 30 for 20 facts about the universe.

If you've been keeping your eye on the news recently, you would have seen that China suspected that they'd made contact with alien life three times... and then the statement was revoked. In this issue, we look into why, so be sure to turn to page 48 to learn more.

That's it from me – I'll leave you to read our special features and regulars. I'll see you again next month!

GEMMA LAVENDER
Content Director

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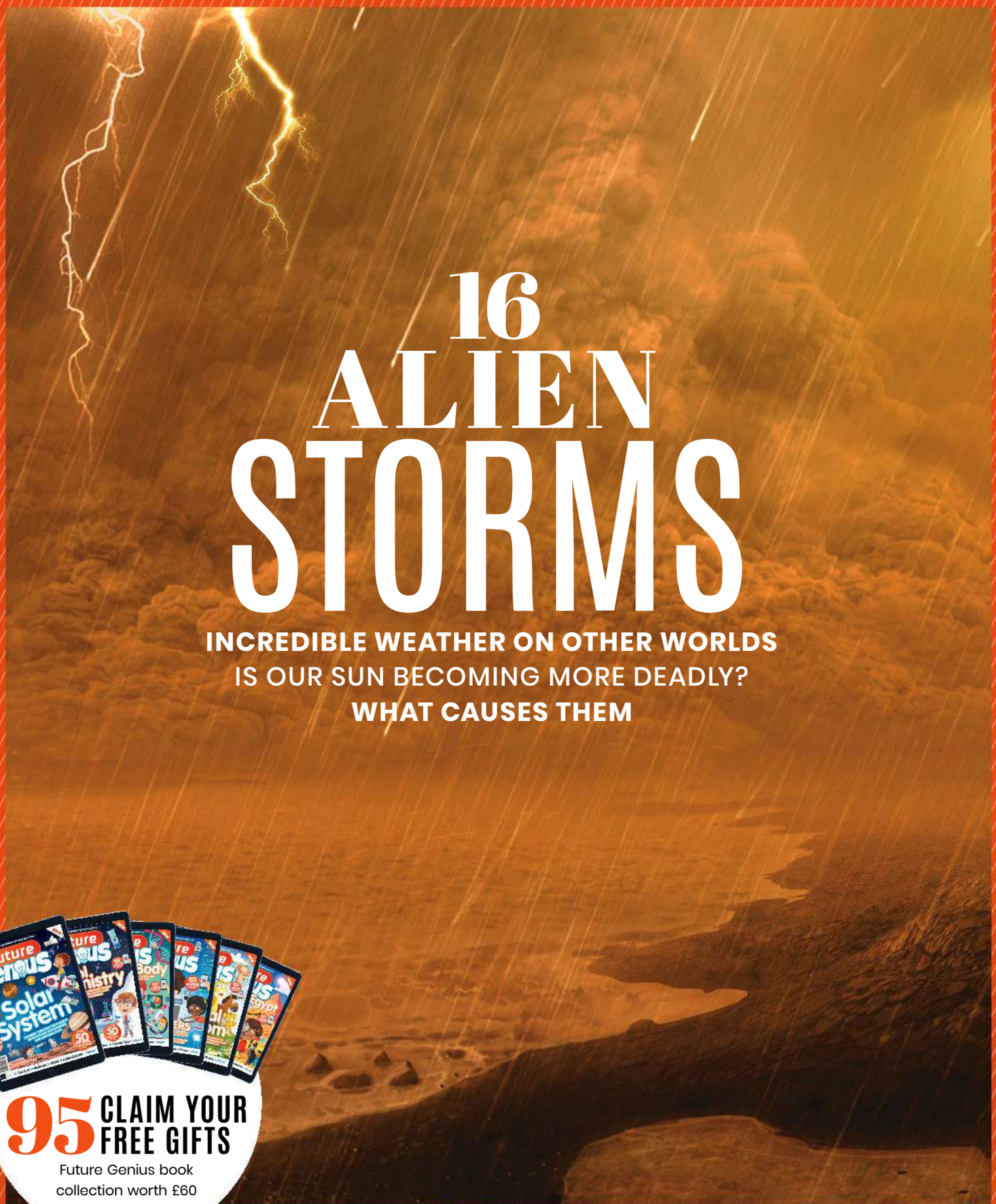

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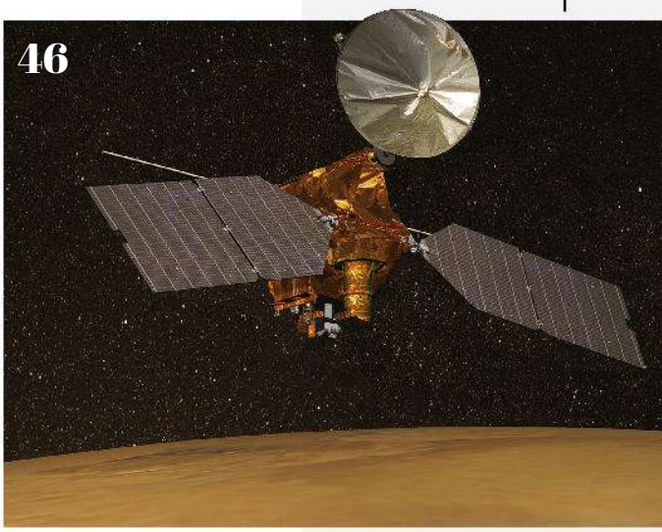

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Three signals supposedly of an extraterrestrial origin were reported – and then redacted

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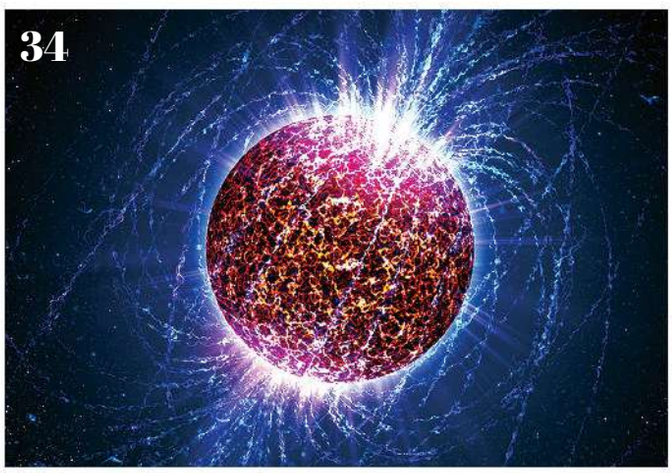

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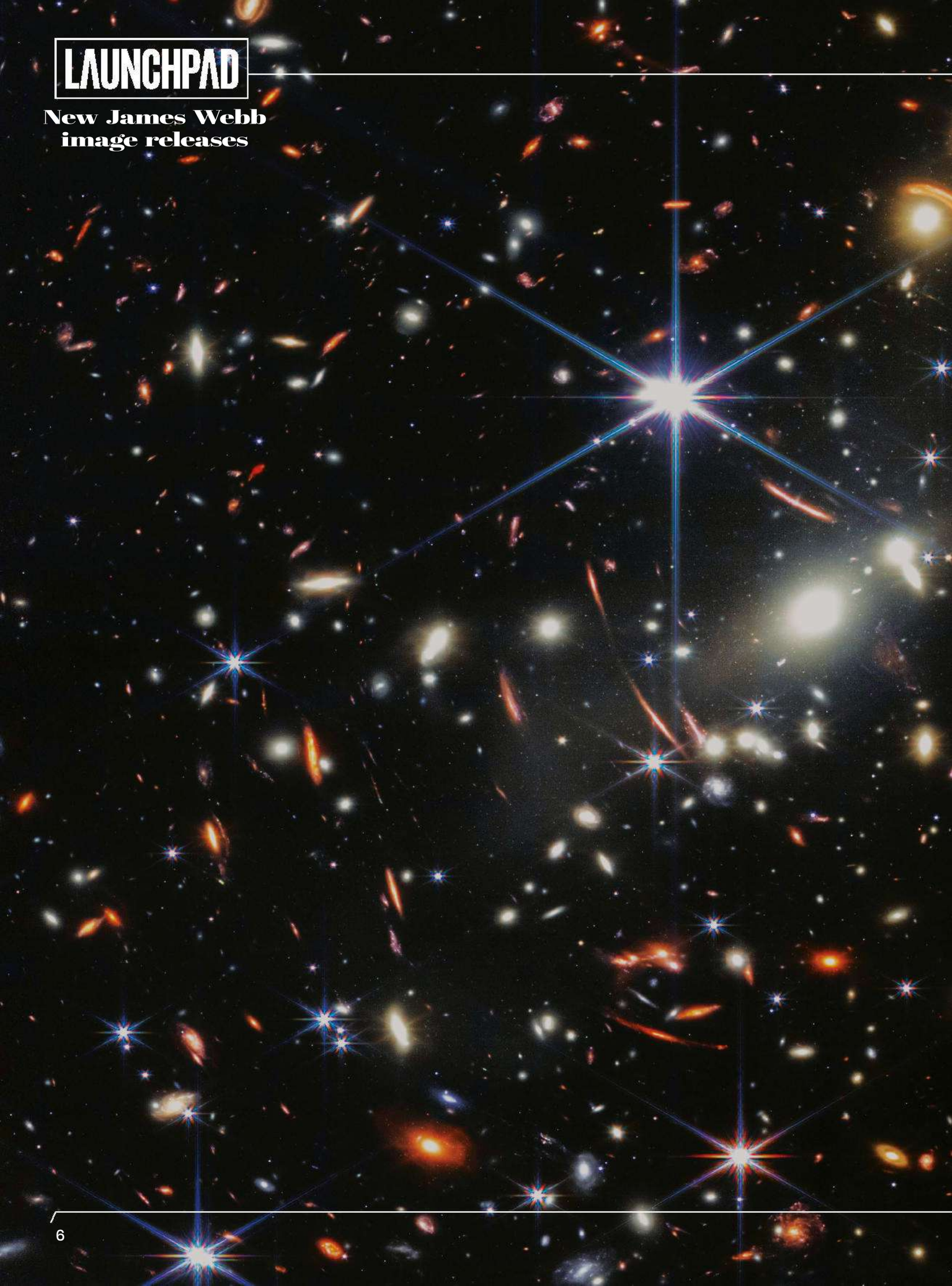
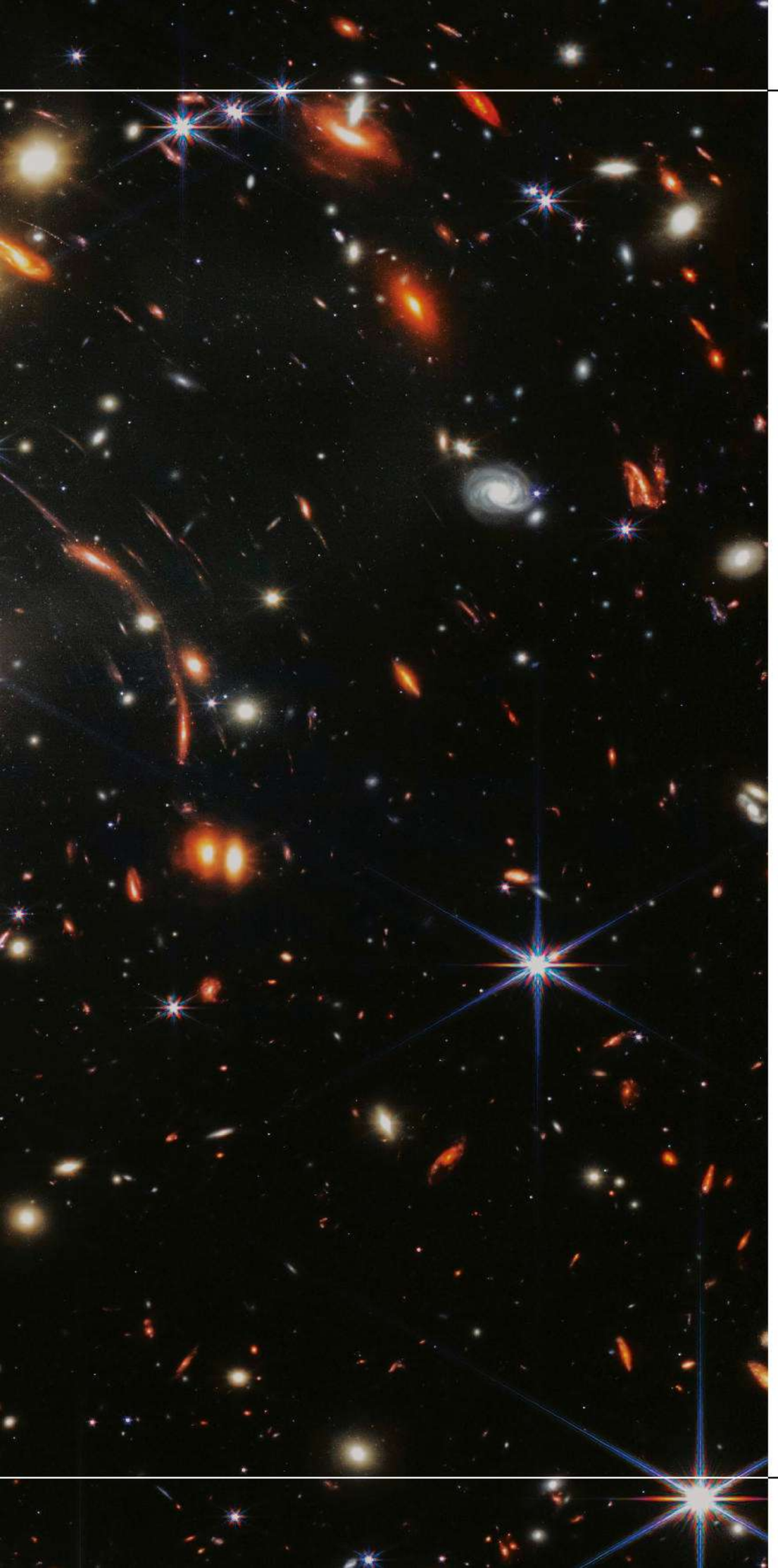
New James Webb image releases





11 July 2022

Webb's first deep field

NASA released the very first science-quality image from the James Webb Space Telescope (JWST) on 11 July. The image, dubbed Webb's First Deep Field, is the deepest infrared view of the universe to date, making use of both Webb's powerful optics and the technique of gravitational lensing to see the galaxy cluster SMACS 0723 as it looked 4.6 billion years ago. "It's really gorgeous and it's teeming with galaxies," Jane Rigby, an astrophysicist at NASA's Goddard Space Flight Center, said of the deep-field image during the live event unveiling all the new images. "We can't take a blank sky. Everywhere we look, there's galaxies."

And although the Hubble Space Telescope took a similar image, that work required days and days of observations. "With Webb, we took that image before breakfast," Rigby said.

Webb's First Deep Field was captured by the observatory's Near-Infrared Camera, or NIRCam, which was the final instrument on the telescope to be approved for full science operations.

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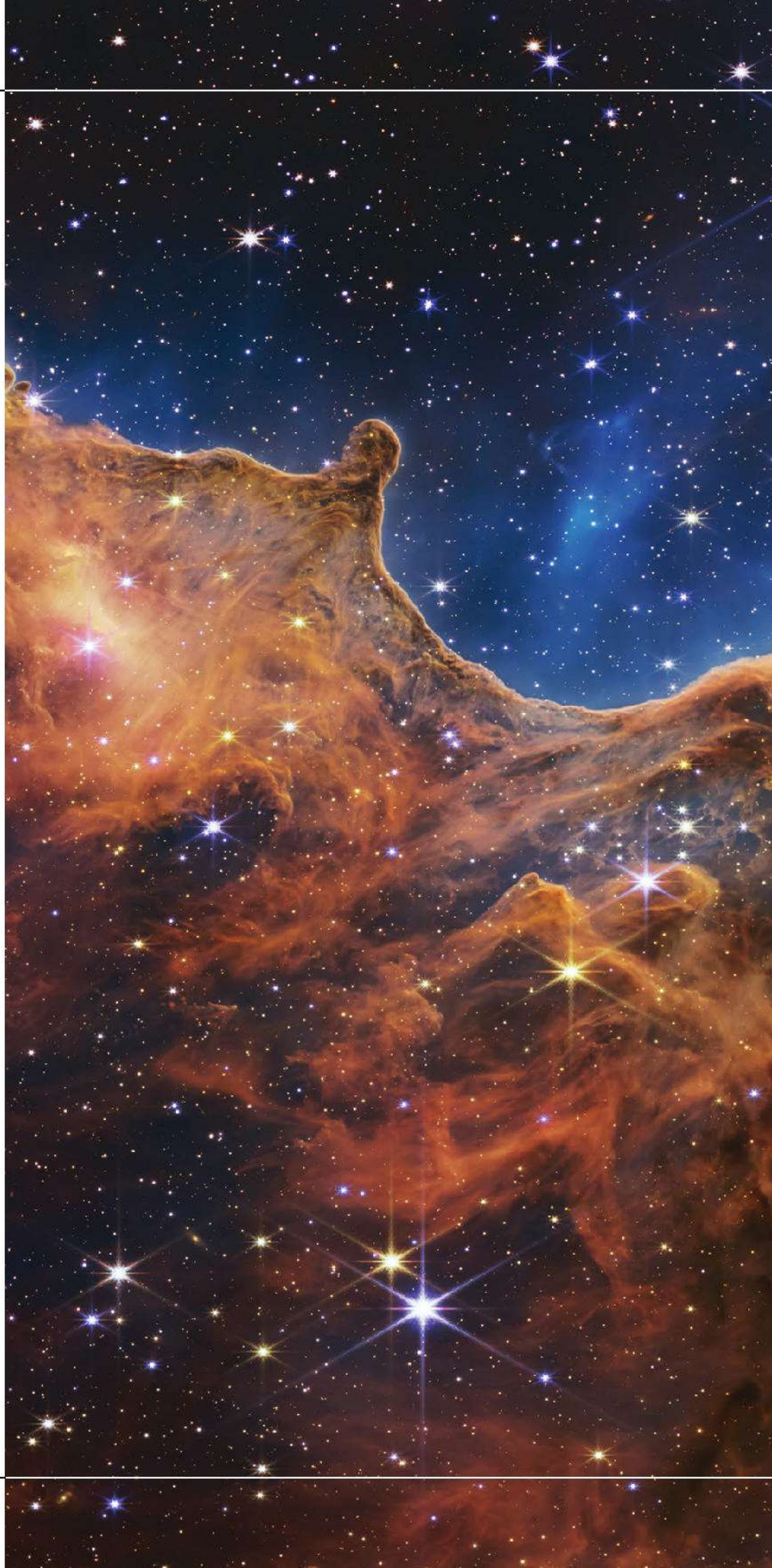
New James Webb image releases



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12 July 2022

Carina Nebula

The Carina Nebula is a massive cloud of dust and gas located about 7,500 light years away from Earth where stars are both forming and dying. And Webb's view of the nebula, which combines near-infrared and mid-infrared light, offers a whole new look at its activity. "There's so much going on here; it's so beautiful," Amber Straughn, an astrophysicist at NASA's Goddard Space Flight Center in Maryland, said. "Today, for the first time, we're seeing brand-new stars that were previously completely hidden from our view."

New James Webb image releases

12 July 2022

Stephan's Quintet

Also among the new images was a view of Stephan's Quintet, a collection of five galaxies. Three of these galaxies display elongated, spiral-like shapes created by the interactions of the galaxies, a few of which will collide someday in the distant future. In addition, this image is the largest from Webb to date, including more than 150 million pixels from nearly 1,000 individual photographs.

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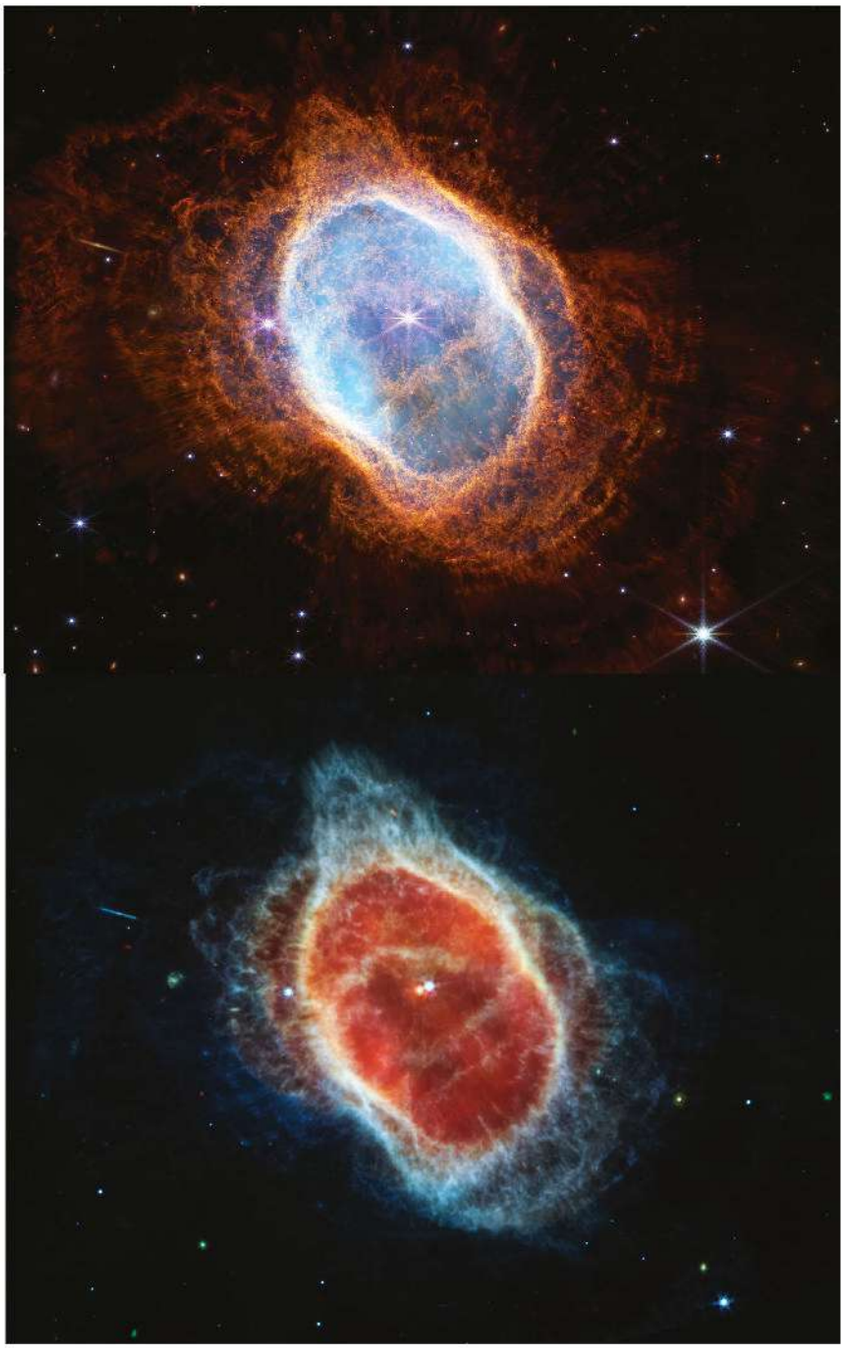
Southern Ring Nebula

Webb's second image displays the Southern Ring Nebula. On top is the view from Webb's NIRCam instrument, showing the nebula in near-infrared light. On the bottom is the view from the observatory's MIRI instrument, which reveals mid-infrared light. That MIRI image is particularly special, said Karl Gordon, an astronomer at the Space Telescope Science Institute: "We knew this was a binary star, but we didn't really see much of the actual star that produced the nebula." MIRI's view displays both stars at the nebula's heart.



Chinese project will bounce signals off asteroids to see how dangerous they are to Earth

Words by Andrew Jones

A leading Chinese university has begun constructing an array of more than 20 large radar antennas to track asteroids that have the potential to be hazardous to Earth.

The project, named China Fuyan (or "compound eye"), is led by the Beijing Institute of Technology. The array aims to bounce signals off asteroids within 93 million miles (150 million kilometres) of Earth (about as distant as the Sun) to image and track objects and determine the possibility that they could impact our planet.

So far, two antennas have been constructed at a site in Chongqing, in southern China. The pair is expected to be tested and become operational by September, according to the Chinese-language outlet Science and Technology Daily, which first reported the development.

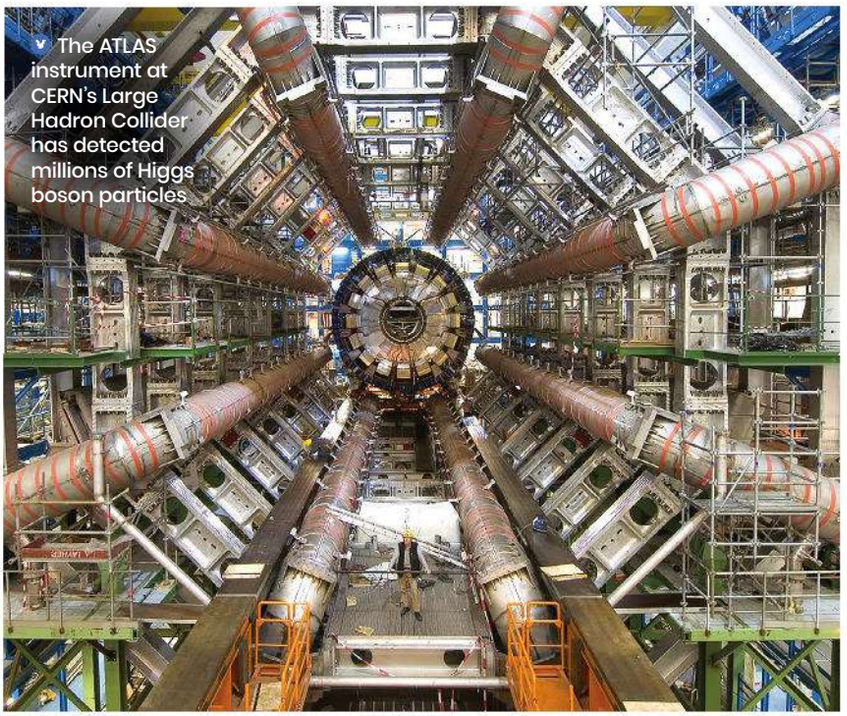
The finished system will include more than 20 radar antennas, each with a diameter of 82 to 98 feet (25 to 30 metres). Chinese news reports claim that the system will be the world's farthest-reaching radar system, but few details about the project, such as the wavelengths at which it will operate are available.

Long Teng, president of the Beijing Institute of Technology, told Beijing news outlet Global Times that the project will meet the country's requirements for near-Earth defense and space sensing capability, as well as frontier studies on the formation of asteroids. The system could also have applicability for tracking satellites and debris in Earth orbit.

In April, the China National Space Administration announced that it is working on a planetary defense plan that includes tracking near-Earth objects and launching an asteroid-deflection test mission in the next few years.

The new decadal survey by the US National Academies of Sciences, Engineering and Medicine found that ground-based radar could be one of humanity's best tools for protecting Earth against asteroids.

An artist's depiction of an asteroid flying past Earth



The ATLAS instrument at CERN's Large Hadron Collider has detected millions of Higgs boson particles

Higgs boson behaves just as expected, 'comprehensive studies' confirm

Words by Tereza Pultrova

The "most comprehensive studies" of the Higgs boson conducted to date reveal that the particle behaves just as expected and could help unlock some of the greatest mysteries of physics, including the nature of dark matter, scientists say. Two new studies, based on 10,000 trillion proton-on-proton collisions conducted inside the Large Hadron Collider (LHC) during its second run, which ended in 2018, analysed 8 million Higgs boson particles detected by the LHC's ATLAS and CMS detectors. The studies were published on 4 July, the 10th anniversary of the Higgs boson discovery by the LHC, the world's largest particle smasher. They show that the particle behaves just as predicted by the Standard Model of particle physics, the all-encompassing theory describing how the basic building blocks of the universe hold together.

> **"Sketching such a portrait this early on was unthinkable before the LHC operated"**
>
> **Luca Malgeri**

The Higgs boson plays a prominent role in the Standard Model. The particle is a carrier of an all-pervading quantum field, known as the Higgs field, which gives other elementary particles their mass. During the experiments, physicists studied how Higgs bosons interact with each other and also with other particles. Such interactions frequently lead to Higgs bosons decaying into other particles, and scientists believe that, somewhere in this chain reaction, they could produce dark matter, the elusive substance that no one has ever seen directly but which is believed to make up about 80 per cent of all matter in the universe. "Sketching such a portrait of the Higgs boson this early on was unthinkable before the LHC started operating," CMS spokesperson Luca Malgeri said. "The reasons for this achievement are manifold and include the exceptional performances of the LHC and of the ATLAS and CMS detectors, and the ingenious data analysis techniques employed."

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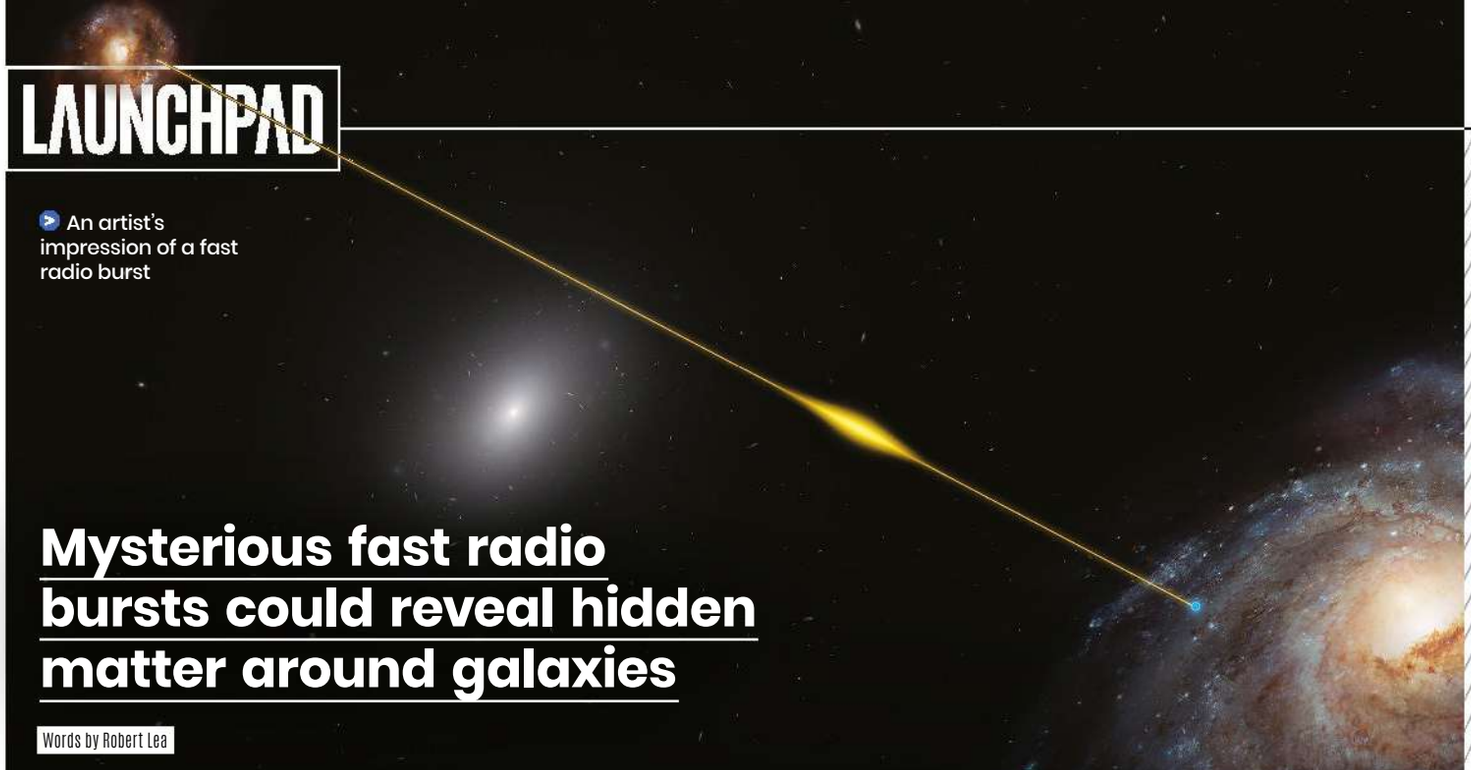

An artist's impression of a fast radio burst

Mysterious fast radio bursts could reveal hidden matter around galaxies

Words by Robert Lea

Rapid bursts of radio waves that originate millions to billions of light years away from Earth could be used as probes to investigate halos of difficult-to-see diffuse gas surrounding nearby galaxies. New research shows that these pulses, called fast radio bursts (FRBs), slow as they pass through the gas enveloping the galaxies between their source and Earth. This also has the effect of dispersing their radio frequencies. Researchers from Caltech found twice as much material as previously believed in these envelopes that enshroud galaxies. This has implications for how these collections of stars and planets evolve over time.

The astronomers looked at a sample of 474 distant FRBs with the Canadian Hydrogen Intensity Mapping Experiment (CHIME) confirming that 24 FRBs intercepted by galactic halos were indeed slowed down compared to others that travelled to Earth unimpeded. Thus, this effect can be used to probe the material through which the FRB passes. "Our study shows that FRBs can act as skewers of all the matter between our radio telescopes and the source of the radio waves," Tolman Postdoctoral Scholar Research Associate in Astronomy at Caltech, Liam Connor, said in a statement. "

Astronomers have found that there is more matter in gas haloes than previously believed. "These gaseous reservoirs are enormous," Connor said. "If the human eye could see the spherical halo that surrounds the nearby Andromeda galaxy, the halo would appear one thousand times larger than the Moon."

Mars spacecraft may have to dig deeper than thought to find traces of life

Words by Robert Lea

Mars rovers may have to dig deeper to find signs of ancient life. New research shows that certain protein-building amino acids that could be evidence of ancient life on Mars are more susceptible to radiation than scientists thought, meaning any amino acids left by life-forms might have only survived if they were buried deep beneath the planet's surface. "Our results suggest that amino acids are destroyed by cosmic rays in the Martian surface rocks and regolith at much faster rates than previously thought," Alexander Pavlov, a space scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, said. "Current Mars rover missions drill down to about two inches (around five centimetres). At those depths, it would take only 20 million years to destroy amino acids completely."

While 20 million years might seem like an incredibly long time, this is a brief period in the development of planets and life. That's especially true when you consider that the signs of life that rovers such as Curiosity are searching for on Mars would have been present billions of years ago. The team discovered that the presence of liquid water, which was abundant on Mars billions of years ago, and perchlorate (charged ions of a chlorine atom surrounded by four oxygen atoms) could have sped up the destruction of amino acids.

To address the problem, searches could shift their focus to locations where geological processes have brought buried rock to the surface. "Missions with shallow drill sampling have to seek recently exposed outcrops – for example, recent microcraters with ages less than 10 million years or the material ejected from such craters," Pavlov said. "Our work is the first comprehensive study where the destruction of a broad range of amino acids was studied under a variety of Mars-relevant factors (temperature, water content, perchlorate abundance) and the rates of radiolysis were compared," Pavlov said.

The research suggests that rovers aren't digging deep enough beneath the Martian surface to discover signs of life

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B: Black and white

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ALIEN STORMS

INCREDIBLE WEATHER ON OTHER WORLDS

IS OUR SUN BECOMING MORE DEADLY?

WHAT CAUSES THEM

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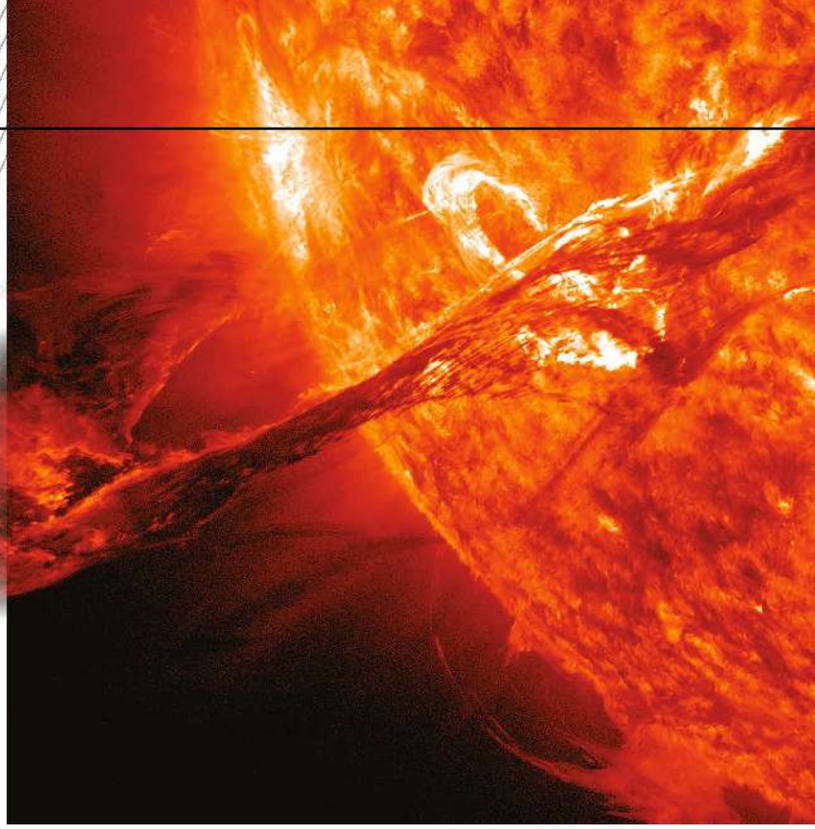
OUR ANGRY, STORMY SUN



We know our Sun as a brilliantly bright sphere that rises in the east and sets in the west each day. That's a simple way to describe it; what really occurs on its surface is far from the impression it gives as it hangs, almost calmly, in the daytime sky.

While going near the Sun would be suicide, with the searing heat and penetrating radiation combining to fry you alive in your spacesuit, technology has revealed this star to be an angry, bubbling cauldron of solar activity.

First up are solar flares – bursts of radiation from the sudden release of magnetic energy from active regions on the Sun's surface, the photosphere. These regions are centred on sunspots, which are tangled knots of magnetic fields. The flares release as much as a sixth of the total amount of energy that the Sun releases every second, with much of it in X-rays or ultraviolet light. The energy of a flare can drive a cloud of charged particles to escape the solar corona in a coronal mass ejection (CME). The CME becomes a giant cloud of plasma hurtling through space and, when CMEs are pointed towards Earth, they cause solar storms.

When a CME strikes the Earth's magnetosphere, it overloads the system and becomes a geomagnetic storm. Earth's magnetosphere is compressed to breaking point with charged particles flooding the magnetic field lines that loop down on to the magnetic poles of the planet. The particles excite atmospheric gases (mainly oxygen and nitrogen), causing them to glow in eerie shimmering curtains of light – the aurora borealis (northern lights) and the aurora australis (southern lights). Oxygen gas glows green, while nitrogen glows purplish-red – the two primary colours seen in auroras. Usually, low-level solar wind activity means that the 'auroral arc' is kept, in the northern hemisphere, to the Arctic Circle, but the power of a geomagnetic storm can see the auroral arc extend to more southerly latitudes over Britain and western Europe, as far south as Spain or even, on very rare occasions, Florida in the United States. The most severe solar storm on record was the Carrington event of 1859, when auroras lit up the skies as far south as the tropics and telegraph wires began to short, sparking electricity.

Those telegraph wires remind us that auroras are only the pretty side of a geomagnetic storm. Although they are not directly harmful to people on the ground, a storm instigated by a powerful CME can destroy our technology. Satellites can short-circuit, knocking out communications.

The Sun's surface is a hive of constant and violent solar activity

A solar prominence is an eruption of hydrogen gas from the Sun's surface

The aurora borealis (northern lights) and aurora australis (southern lights) can be seen in the northern and southern hemispheres of our planet

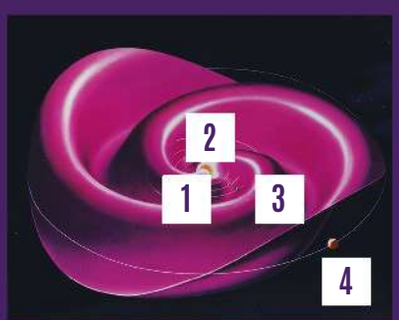
SOLAR WIND CURRENT

1 Surface of the Sun
As the solar wind rises it simplifies until it consists of two polarities separated by the line of the heliospheric current sheet.

2 Corona
In the corona, the solar wind begins to draw out the heliospheric current sheet into space, extending the Sun's atmosphere out into the rest of the Solar System.

3 Rotation
As the Sun rotates, it causes the heliospheric current sheet to become twisted.

4 Jupiter
Material in the heliospheric current sheet takes three weeks to reach Jupiter. The sheet extends into the Kuiper belt, where Voyager is exploring.



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HOW SOLAR RADIATION STORMS ARE CLASSIFIED

MINOR

50 per 11-year solar cycle

A minor solar radiation storm causes minimal impact on high-frequency (HF) radio in the polar regions, but otherwise causes no damaging effects.

MODERATE

25 per cycle

A moderate storm affects navigation at the polar caps and may, in rare instances, cause problems in satellites, but poses no threat to humans.

STRONG

10 per cycle

During a strong storm, astronauts are advised to seek shelter, while satellites could lose power and instrument usage. HF radio will degrade at the poles.

SEVERE

3 per cycle

Astronauts and passengers on planes may be exposed to radiation, while satellites could experience orientation problems. HF radio blacks out at the poles.

EXTREME

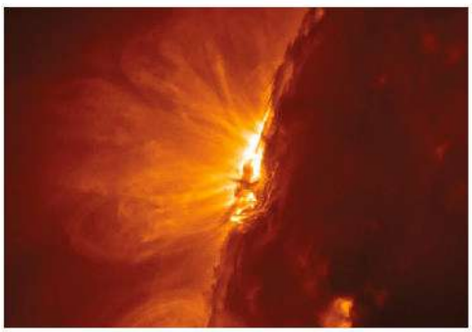
Less than 1 per cycle

Astronauts and aeroplane passengers exposed to high radiation. Satellites may be rendered useless. HF communications black out in polar regions.

Astronauts must shelter from radiation in a shielded room on board the International Space Station. On the ground, power lines can be swamped by raw current from the CME plasma – in 1989, a solar storm caused a nine-hour blackout in Quebec in Canada. In our modern world, the nightmare scenario is that a powerful enough solar storm could stop everything working, wiping computers, crashing the internet, knocking out power systems and disrupting communications. The world would be sent into technological, social and economic chaos.

We're most vulnerable to solar storms at solar maximum, the point in the Sun's 11-year cycle of activity when our nearest star is most active. Solar flares happen all the time, and CMEs strike Earth frequently, but rarely are they as powerful as the solar activity that plunged Quebec into darkness. However, scientists are currently unable to predict solar activity or when the next big CME will be.

All of this takes place in the Sun's heliosphere, which is the extent of its magnetic influence throughout the Solar System, where the solar wind still blows. The heliosphere goes out past the orbit of Pluto. The Voyager 1 spacecraft is 118 times further from the Sun than Earth is, yet it has still to leave the heliosphere. CMEs disperse and lose power the deeper they get into the Solar System. However, solar activity can still have an effect, even on the edge of the heliosphere. Both Voyager 1 and 2 have experienced the heliosphere swelling and shrinking on gusts of the solar wind that inflate the Solar System's magnetic bubble.



HOW CAN A SPACECRAFT HELP?

How ESA's bold proposal would help predict incoming solar weather

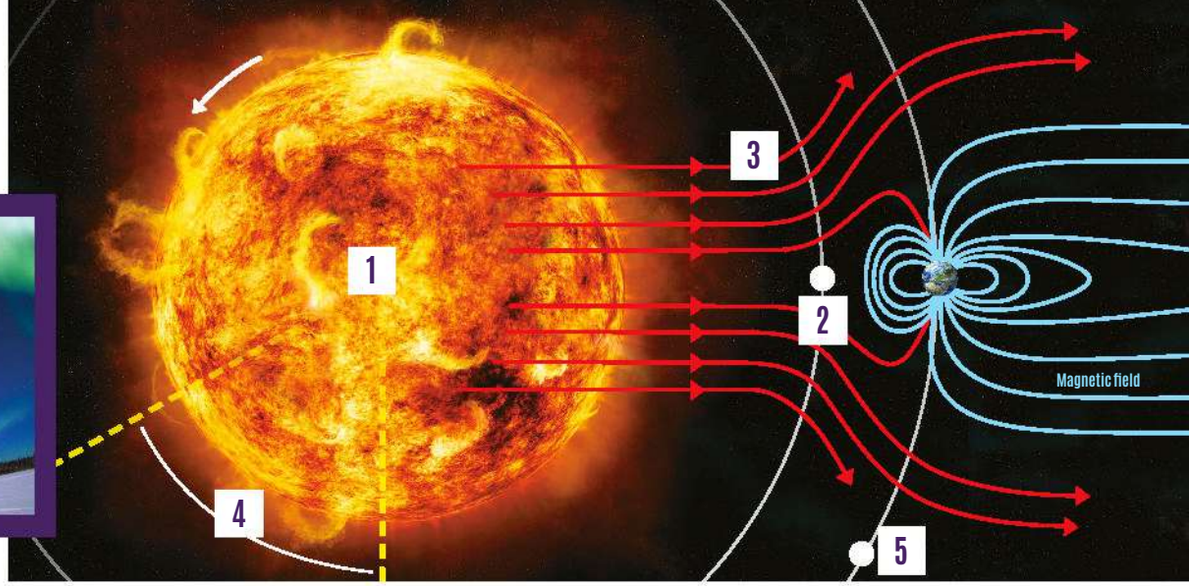
1 The Sun
As the Sun rotates, a coronal mass ejection (CME) or solar flare can come into view.

2 L1
L1 sees solar weather at the same time as Earth, so doesn't give the same advance warning.

3 Incoming particles
L5 could give us more accurate information on particles heading for Earth.

4 Advanced warning
Ships at L5 would see the Sun up to five days before it rotates into view of Earth.

5 L5
L5 is about 60° behind Earth. A probe here can judge the speed of solar ejections heading to Earth.



DUST STORMS THAT COVER THE PLANET

Now, this is really bad weather – a dust storm that doesn't just cover an area, or even a hemisphere, but the entire planet. During summer in the Red Planet's southern hemisphere, when Mars is at its closest point to the Sun, solar heating can drive immense storms that blow up red dust and can obscure the surface for months. In 1971, when Mariner 9 arrived on Mars, it found the whole planet hidden under a veil of dust, with only the volcano Olympus Mons visible. More recently, the Mars Exploration Rovers Spirit and Opportunity would struggle to survive in dust storms as the Sun's light was blocked and their solar panels covered by a coating of dust.

On Earth, moisture arms swirling storms, but on Mars there is only dust. Normally most of the dust is on the ground, but some is found in the atmosphere, where it scatters sunlight and makes the sky appear pinky-red. When Mars is at its hottest – still cold enough to freeze water – the atmospheric dust can absorb the energy of the sunlight, which causes warm pockets of air to rapidly move towards colder, low-pressure regions, generating winds of up to 45 metres per second (162 kilometres per hour or 100 miles per hour) that begin to pick up dust particles from the ground, adding to the atmospheric dust content and increasing heating, pushing the winds harder and faster until the atmosphere is filled by dust.

And then, just as quickly, the storm can die down. Perhaps by blocking the sunlight, the surface of Mars grows cooler, allowing some of the dust to begin sinking out of the atmosphere. Not all dust storms swallow the entire planet – some are more localised events. However, were you to be on the surface during a dust storm, other than the sky darkening and a fine coating of dust settling over you, the atmosphere is so thin that you'd barely notice the wind or the scouring dust.

Snaking its way across Mars's surface, this dust devil is powered by solar heating just like the dust plumes found on Earth

HOW DO DUST STORMS FORM?

1 Heating up the atmosphere

The absence of clouds or water means radiation cannot be reflected back into space, and the thin atmosphere close to Mars's surface becomes hotter than the atmosphere above it.

2 Picking up the dust

As the atmosphere is heated, dust is lifted into the air and, after absorbing more sunlight, the dust warms up the atmosphere further, propelling more dust into the air.

3 The storm begins

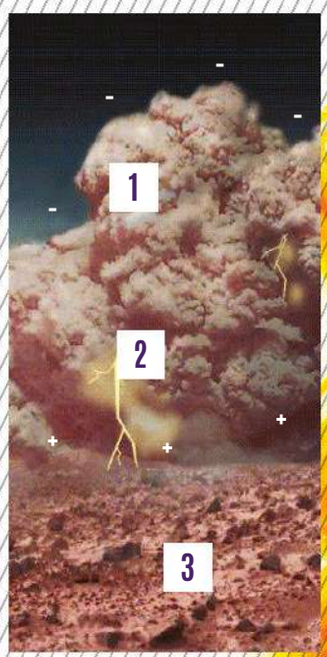
The change in temperature creates winds, swirling at great speeds of 96 to 193km/h (60 to 120mph), capable of dominating the entire planet.

KICKING UP DUST

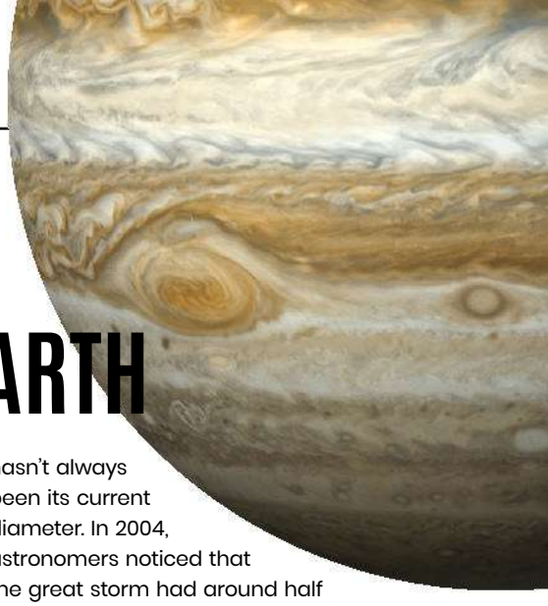
1 Desert dust
The dust storms that frequently rise from the cold deserts of Mars, sometimes rage across the entire Martian globe, which crackle and snap with electricity.

2 Electrifying dust
It is possible that dust particles could be electrified in Martian dust storms when they rub against each other as they are carried by the winds, transferring positive (+) and negative (–) electric charges.

3 Strong swirls
Electric fields generated by dust are thought to be strong enough to break apart carbon dioxide and water molecules in the Martian atmosphere, recombining to make reactive chemicals like hydrogen peroxide, which you'll find in bleach and ozone.



HURRICANES BIGGER THAN EARTH



Easily one of the most famous storms in the Solar System, Jupiter's Great Red Spot is so large that it is visible through many Earth-based telescopes.

The Great Red Spot is thought to have been in existence for at least 340 years. The oval red eye rotates anticlockwise due to the crushing high pressure on the planet. Winds can reach over 400 kilometres per hour (250 miles per hour) around the spot. However, inside the storm they seem to be nearly non-existent. And that's not all; this complicated weather system has an average temperature of about -162 degrees Celsius (-260 degrees Fahrenheit).

At around eight kilometres (five miles) above the surrounding clouds and held in place by an eastward jet stream to its south and a very strong westward jet flowing into its north, the Great Red Spot has travelled several times around Jupiter, but how did such a behemoth of a storm come to appear on the gas giant's surface?

The answer is not clear, despite the efforts of planetary scientists. However, experts do theorise that the storm is driven by an internal heat source, and it absorbs smaller storms that fall into its path, passing over and swallowing them whole. Another thing they know is that the Great Red Spot hasn't always been its current diameter. In 2004, astronomers noticed that the great storm had around half the 40,000-kilometre (25,000-mile) diameter it had around 100 years before. If the Great Red Spot continues to downsize at this rate, it could morph from an oval shape into a more circular storm by 2040. You might think this well-known feature won't be sticking around for long as it becomes smaller, but experts believe the storm is here to stay since it is strongly powered by numerous other phenomena in the atmosphere.

Storms like these are not out of place on Jupiter, whose atmosphere is a zigzag pattern of 12 jet streams, with blemishes of warmer brown and cooler white ovals in the atmosphere owed to storms as young as a few hours or stretching into centuries.

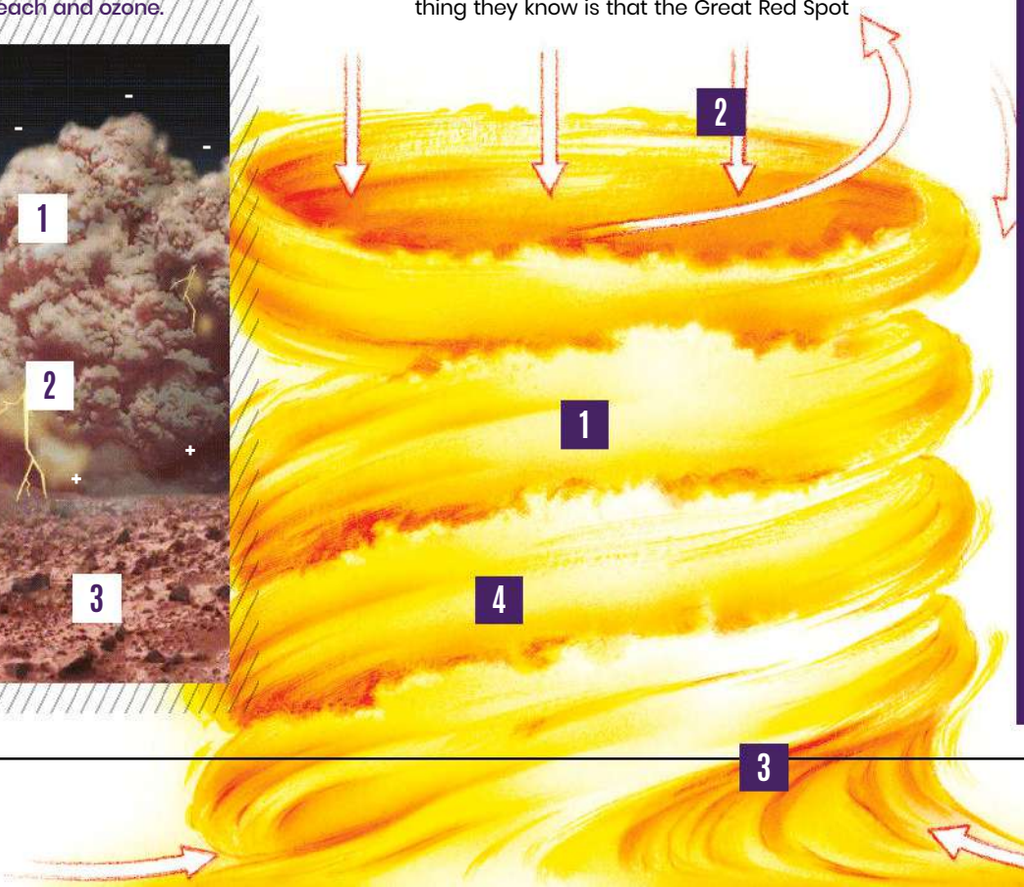
THE SCIENCE OF THE GREAT RED SPOT

1 A constant twirl
Hot gases in the atmosphere constantly rise and fall.

2 Falling cool gas
Cooler gas falls through the atmosphere. Coriolis makes the area whirl, creating eddies.

3 Shifting and merging eddies
Eddies move around and merge, creating more powerful storms.

4 High wind speeds
Winds of the Great Red Spot can reach over 400km/h (250mph).



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THE VIOLENT POLAR VORTEX

On the outside, Saturn almost looks like a calm, bland world, but once in a while, huge storms flare up on the ringed planet. From the short-lived Great White Spot of 1990 to the more recent storm of 2010, which grew into an atmospheric belt covering around 4 billion square kilometres (1.5 billion square miles), Saturn has proven to be a turbulent world. What's more, the storms on Saturn are the second fastest in the Solar System, after ice giant Neptune, peaking at an impressive 1,800 kilometres per hour (1,120 miles per hour) and blowing in an easterly direction.

Temperatures on Saturn are normally recorded at around -185 degrees Celsius (-300 degrees Fahrenheit), but near the giant swirling polar vortex – a persistent cyclone taking pride of place at the ringed planet's south pole – temperatures start to warm up, and while the climate doesn't reach high enough to get a suntan, this -122 degrees Celsius (-188 degrees Fahrenheit) vortex is the warmest spot on Saturn, with a powerful jet stream

Around once every Saturn year (roughly 30 Earth years), huge, storms work their way through the clouds of the northern hemisphere. The storm pictured here, which was imaged in 2011, is the longest storm to date, lasting roughly 200 days

1 Counterclockwise swirl

This storm angrily swirls in an anticlockwise direction, rotating with a period of nearly 11 hours.

2 Monstrous size

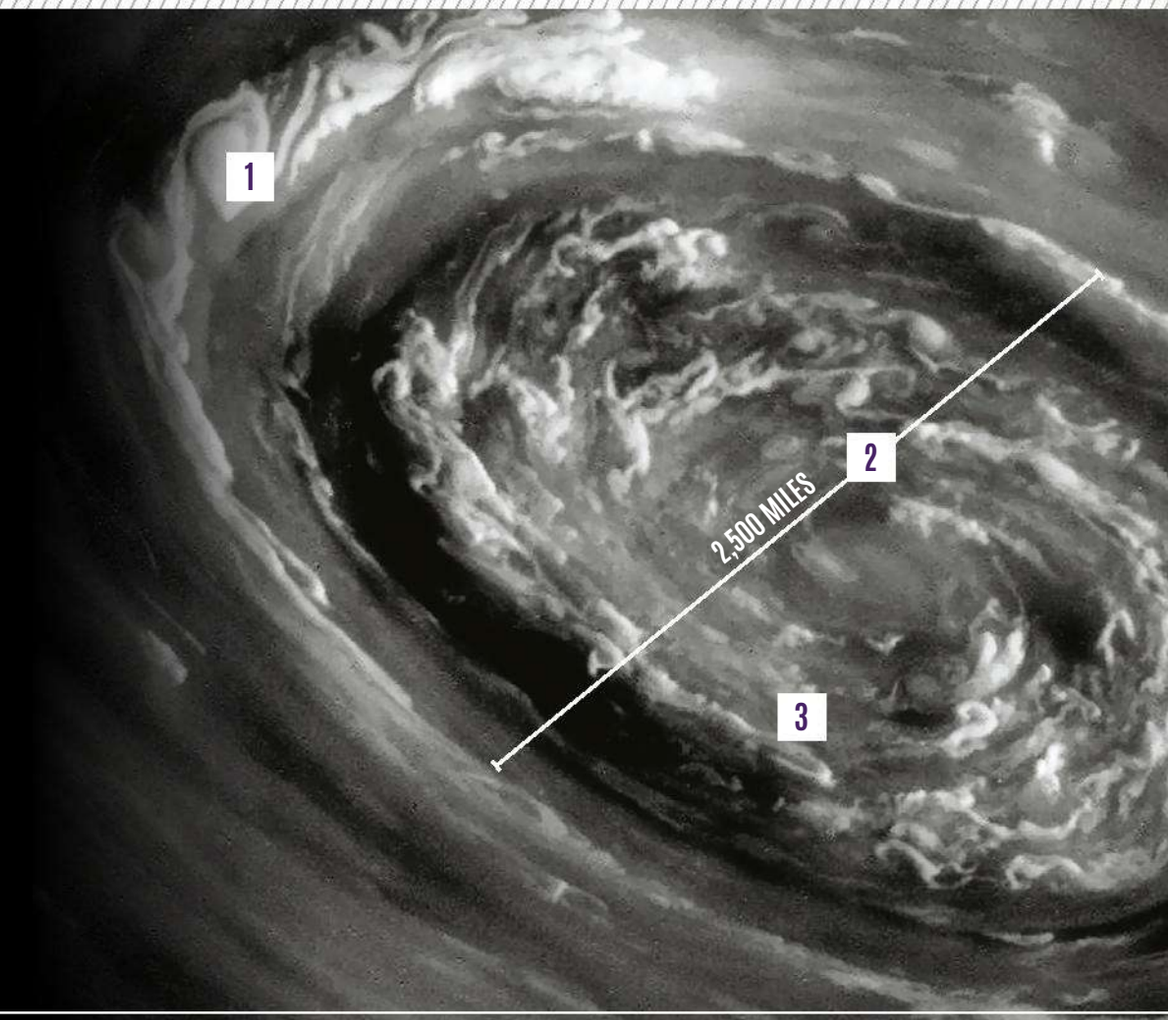
Not only is this storm violent, it is also argued to be an estimated 4,000km (2,500 miles) wide – roughly the distance between New York and Los Angeles!

3 Rolling cloud formation

The bubbling of frothy clouds sit at the centre of Saturn's famed northern vortex, a hexagonal-shaped feature characteristic of the planet's two poles.

4 Fast and furious

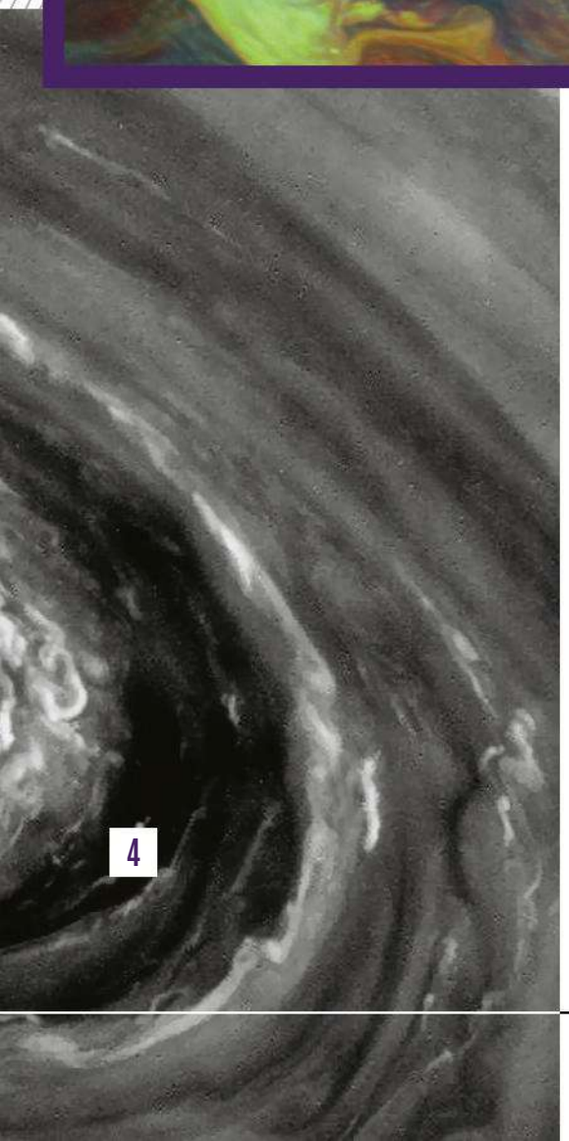
This swirling vortex, located above Saturn's north pole at the centre of a jet stream, whips around at a speed of 480km/h (300mph) and is believed to be at least 30 years old.



smashing its way through this terrifyingly fierce feature.

Saturn's north pole also has a giant storm of its own surrounded by a persistent hexagonal cloud pattern. Spotted in 1980 and 1981 during the Voyager 1 and Voyager 2 flybys, Saturn's hexagon, complete with six clear and fairly straight sides, is estimated to have a diameter wider than two Earths. The entire structure rotates almost every 11 hours.

Sighted more closely by NASA's Cassini spacecraft in 2009 as spring fell on the ringed giant's northern hemisphere, experts believe the storm could have been raging for at least 30 years, whipping around at over 480 kilometres per hour (300 miles per hour) in a counterclockwise direction and disturbing frothy white clouds in its wake.



4

DEADLY METHANE RAIN

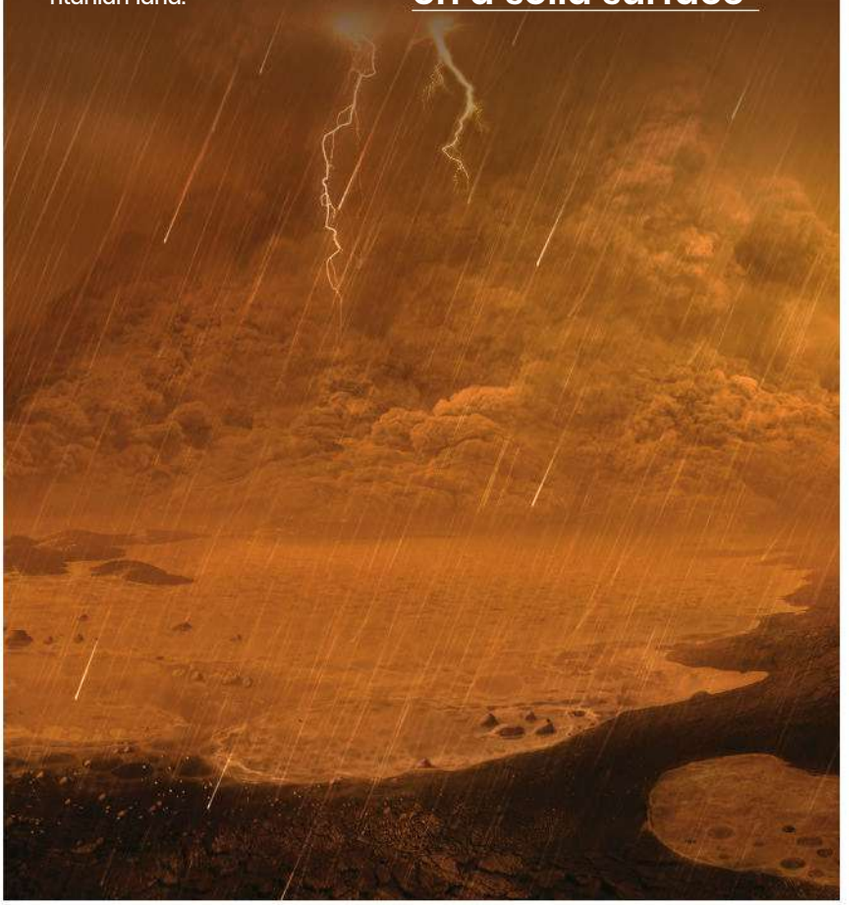
With a surface pressure almost one and a half times that of Earth's, Titan's atmosphere is slightly more massive than our planet's overall, taking on an almost chokingly opaque haze of orange layers that block out any light that tries to penetrate the Saturnian moon's thick cover.

Titan is the only world, other than Earth, where liquid rains on a solid surface. However, rather than the water that we are used to falling from the skies above us, pooling into puddles and flowing as streams and rivers, this moon's rains fall as liquid methane – liquid hydrocarbons that add more fluid to the many lakes and oceans that already cover the surface. It is thanks to the moon's complex methane cycle, similar to the natural processes found on Earth, that this is possible.

Rain falls quite frequently on Earth. However, the same can't be said for some regions on Titan. Spring brings rain clouds and showers to Titan's desert with the moon only experiencing rainfall around once every 1,000 years on its arid equator. However, these rain showers certainly make up for the lack of activity by dumping tens of centimetres or even metres of methane rain on to the Titanian surface.

At the poles of the moon it's a completely different story, however. Methane rain falls much more frequently, replenishing the lakes of organic liquid covering the Titanian land.

"Titan is the only world other than Earth where it rains on a solid surface"



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WINDS AT TWICE THE SPEED OF SOUND

We've all witnessed strong winds here on Earth, from gusts that turn your umbrella inside out to tornadoes that rip up everything in their path. You might think these winds are a force to be reckoned with, but unless you've had a day floating around the gaseous atmosphere of ice giant Neptune, you haven't seen anything yet!

You might think that Neptune's distance from the Sun, which creates temperatures as low as -218 degrees Celsius (-360 degrees Fahrenheit), would mean a world frozen solid by the sub-zero climate with not much going on in terms of weather. However, you would be incorrect. The winds that race through its hydrogen, helium and ammonia-laden atmosphere can reach maximum speeds of around 2,400 kilometres per hour (1,500 miles per hour), making this dark horse probably the most violently stormy world in the Solar System, and making our most powerful winds look like light breezes.

Neptune's fastest storms take the form of dark spots, such as the anticyclonic Great Dark Spot in the planet's southern hemisphere and the Small Dark Spot further south – thought to be vortex structures due to their stable features that can persist for several months – as well as the white cloud group, Scooter.

So what causes these winds? Neptune might be extremely frosty, but astronomers think that the freezing temperatures might be responsible; decreasing friction in the gas giant to the point where there's no stopping those super-fast winds once they get going.

Delving into its layers of gas, we find another possibility pointing to just how these active storms came about as the temperature starts to rise. As things get more snug closer to the centre, the internal energy could be just what is driving the most violent storms that we've ever witnessed.

"Neptune's fastest storms take the form of dark spots"

Long clouds on Neptune's surface are similar to cirrus clouds on Earth

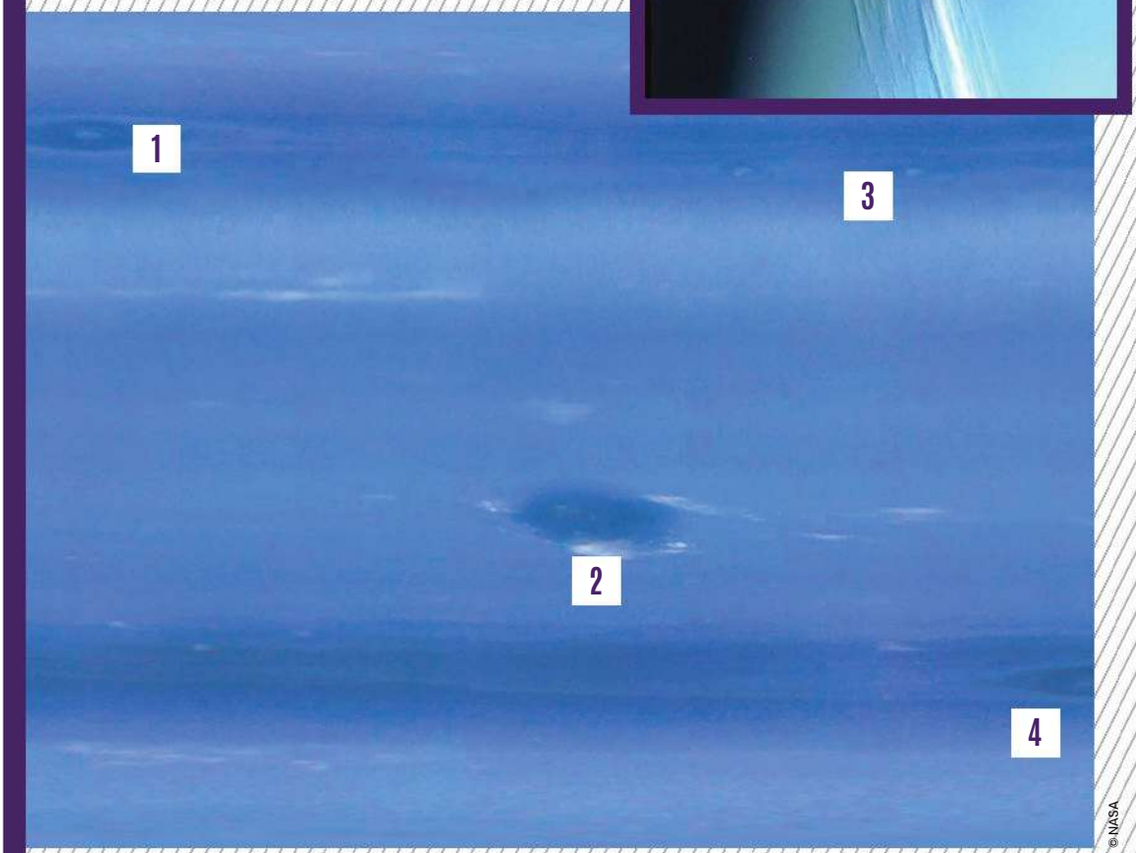
NEPTUNE'S ATMOSPHERE

1 A stormy surface
Storms on the surface appear in the form of blemishes.

2 Great Dark Spot
This anticyclonic storm was replaced by a similar feature called the Northern Great Dark Spot.

3 Clouds and storms
The cyclonic storms are thought to occur in the troposphere at low altitudes compared to the brighter white clouds.

4 Small Dark Spot
This storm, also called The Wizard's Eye, is the second most violent storm on Neptune.



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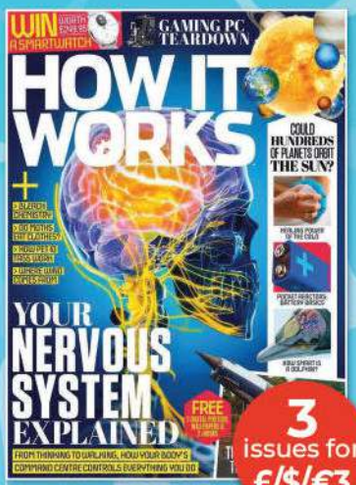

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FUTURE TECH

GAMMA-RAY OBSERVATORY

This far-sighted next-generation telescope array may help answer some of the universe's biggest mysteries

It can be easy to forget that one of the best ways to view the greater universe is to peer far beyond visible light, into the gamma-ray end of the electromagnetic spectrum. With the ability to more efficiently see beyond our Solar System, gamma-ray astronomy is an important field for helping us understand the cosmos.

The Cherenkov Telescope Array (CTA) plans to take the gamma-ray approach one step further than traditional arrays. By looking into much higher energy ranges than ever before, astronomers will be able to observe non-thermal processes, enabling them to research some of the great mysteries of the universe.

Non-thermal radiation is considered to be different from normal radiation occurring on the electromagnetic spectrum. It's thought to be created when elementary particles decay, which are the fundamental building blocks of all matter. However, this process isn't yet completely understood. Cosmic rays are included in this definition, and their source is one of the mysteries that the CTA aims to discover.

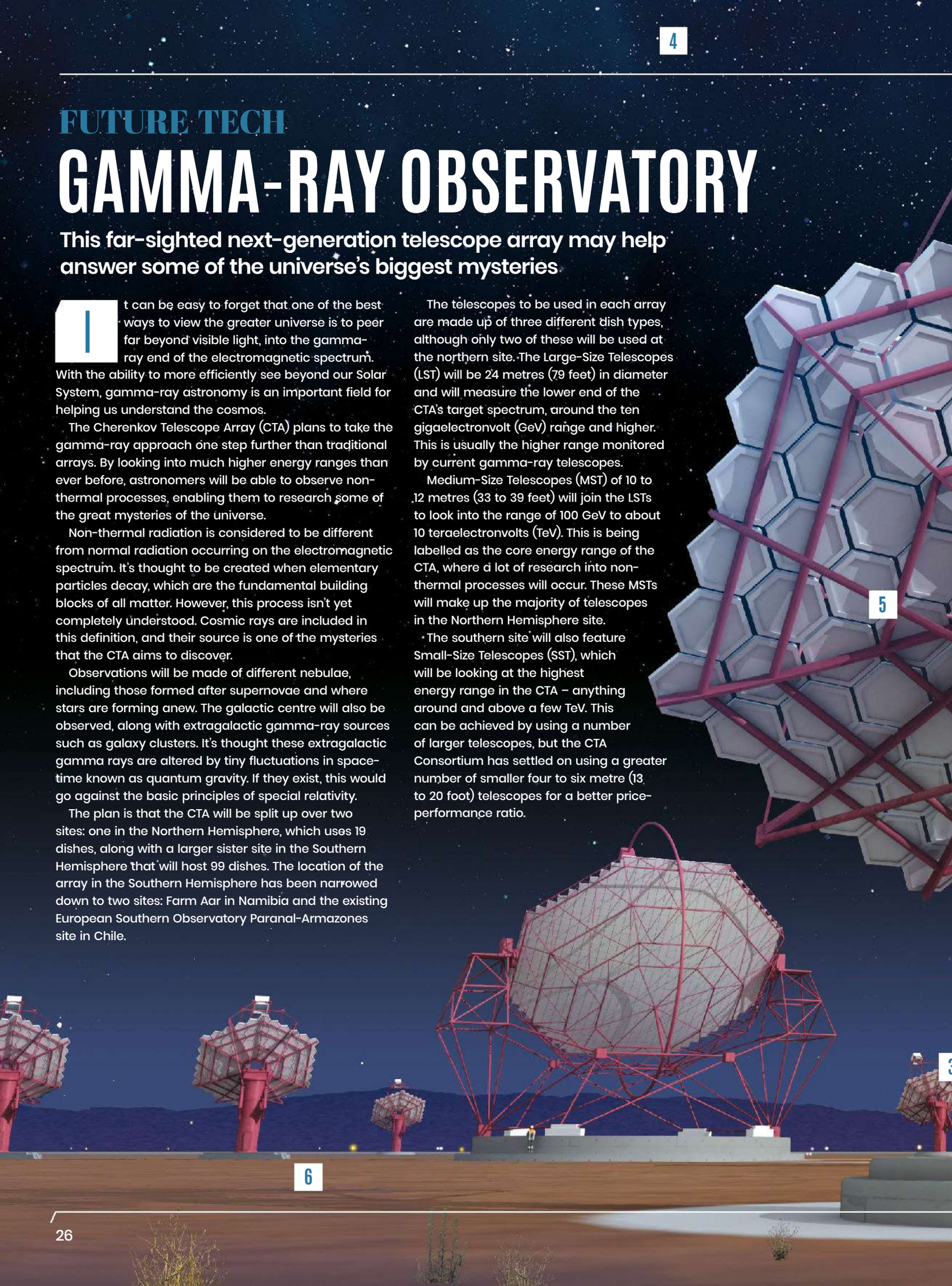
Observations will be made of different nebulae, including those formed after supernovae and where stars are forming anew. The galactic centre will also be observed, along with extragalactic gamma-ray sources such as galaxy clusters. It's thought these extragalactic gamma rays are altered by tiny fluctuations in space-time known as quantum gravity. If they exist, this would go against the basic principles of special relativity.

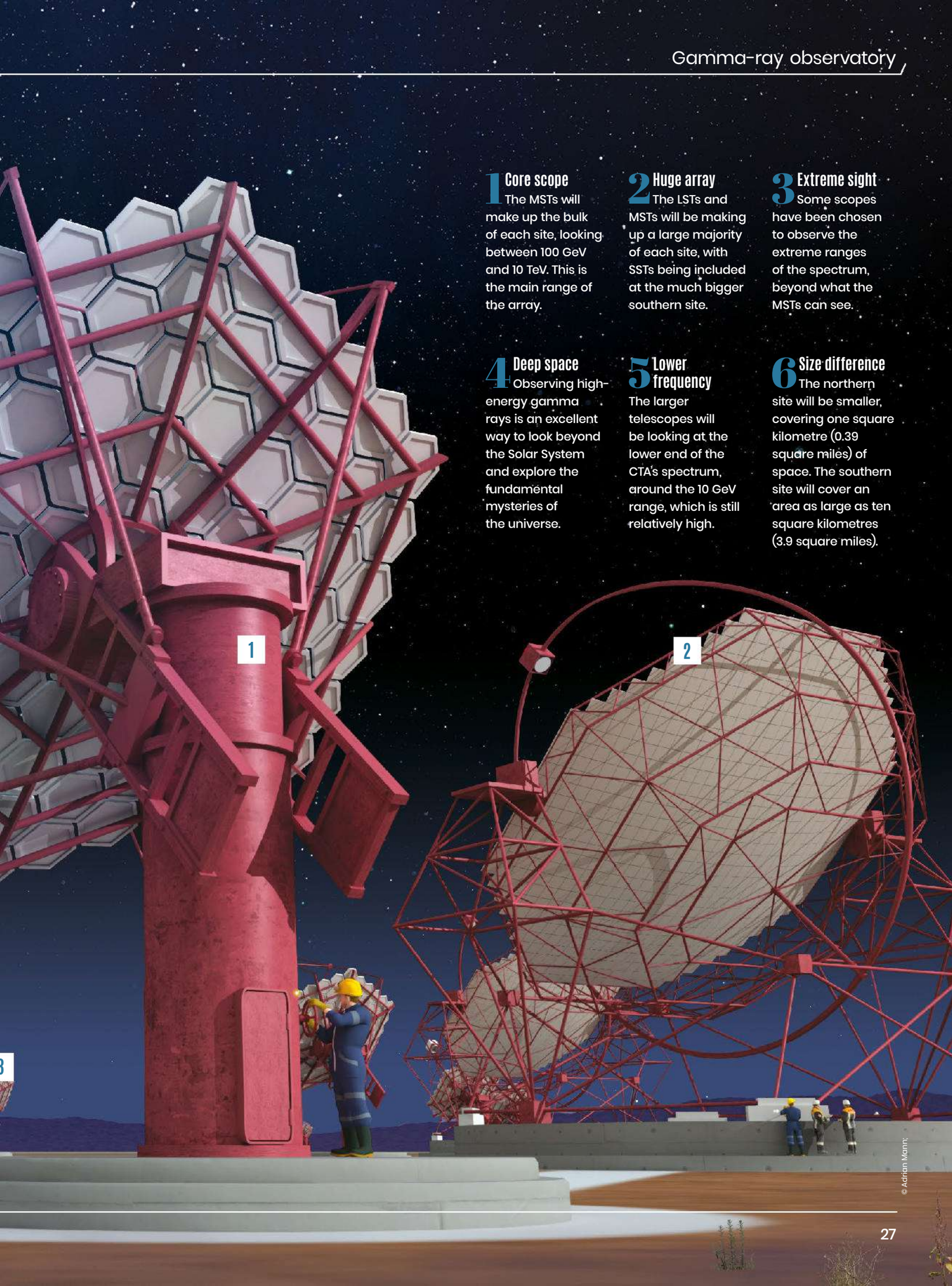
The plan is that the CTA will be split up over two sites: one in the Northern Hemisphere, which uses 19 dishes, along with a larger sister site in the Southern Hemisphere that will host 99 dishes. The location of the array in the Southern Hemisphere has been narrowed down to two sites: Farm Aar in Namibia and the existing European Southern Observatory Paranal-Armazones site in Chile.

The telescopes to be used in each array are made up of three different dish types, although only two of these will be used at the northern site. The Large-Size Telescopes (LST) will be 24 metres (79 feet) in diameter and will measure the lower end of the CTA's target spectrum, around the ten gigaelectronvolt (GeV) range and higher. This is usually the higher range monitored by current gamma-ray telescopes.

Medium-Size Telescopes (MST) of 10 to 12 metres (33 to 39 feet) will join the LSTs to look into the range of 100 GeV to about 10 teraelectronvolts (TeV). This is being labelled as the core energy range of the CTA, where a lot of research into non-thermal processes will occur. These MSTs will make up the majority of telescopes in the Northern Hemisphere site.

The southern site will also feature Small-Size Telescopes (SST), which will be looking at the highest energy range in the CTA – anything around and above a few TeV. This can be achieved by using a number of larger telescopes, but the CTA Consortium has settled on using a greater number of smaller four to six metre (13 to 20 foot) telescopes for a better price-performance ratio.





1 Core scope
The MSTs will make up the bulk of each site, looking between 100 GeV and 10 TeV. This is the main range of the array.

2 Huge array
The LSTs and MSTs will be making up a large majority of each site, with SSTs being included at the much bigger southern site.

3 Extreme sight
Some scopes have been chosen to observe the extreme ranges of the spectrum, beyond what the MSTs can see.

4 Deep space
Observing high-energy gamma rays is an excellent way to look beyond the Solar System and explore the fundamental mysteries of the universe.

5 Lower frequency
The larger telescopes will be looking at the lower end of the CTA's spectrum, around the 10 GeV range, which is still relatively high.

6 Size difference
The northern site will be smaller, covering one square kilometre (0.39 square miles) of space. The southern site will cover an area as large as ten square kilometres (3.9 square miles).

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BIO+

Robert Woodrow Wilson

An American radio astronomer, Robert Wilson graduated from Rice University in Houston before completing his graduate work with the California Institute of Technology. Wilson and fellow astronomer Arno Penzias jointly won the Nobel Prize in Physics for their discovery of the Cosmic Microwave Background (CMB), and they also won the Henry Draper medal of the National Academy of Science in 1977. Wilson worked at Bell Laboratories until 1994, when he was named a senior scientist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, where he is based today.

© Getty

Robert Woodrow Wilson

"Dicke put the phone down and said... 'Boys, we've been scooped!'"

When radiation left over from the heat of the Big Bang was discovered by astronomers Robert Wilson and Arno Penzias in 1964, it caused a revolution in cosmology. All About Space catches up with the Nobel prize-winning Wilson to uncover just how much

Interviewed by Giles Sparrow

What were the origins of radio astronomy at Bell Labs?
I like to start the story in 1928. That was the year Bell Laboratories hired people of interest to us, Art Crawford and Karl Jansky. Karl was tasked with understanding the sources of noise on a proposed transatlantic short wave radio-telephone circuit. He built a large, rotating, directional antenna and sensitive radio receiver and recorded his output for a long time. In addition to thunderstorms and man-made noise, just like old AM radios used to produce, he found a hiss of noise that repeated every day. In 1933, after several years of observation, he identified the source as the centre of our galaxy. This started the science of radio astronomy.

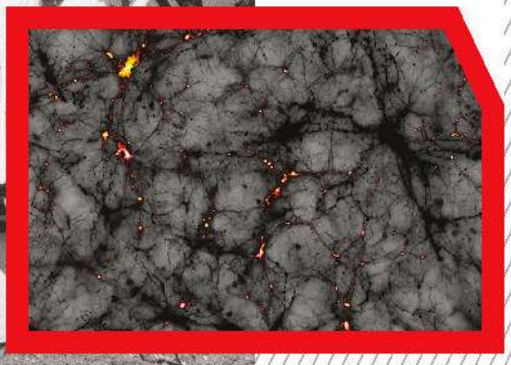
Moving ahead, in 1958 NASA launched the 100-foot diameter Echo balloon made of aluminised mylar, so think of an aluminised party balloon 100 feet in diameter on the very edge of space. It had to be very light so that if there was any atmosphere up at that elevation, it would affect the balloon very quickly. Bell Labs proposed using Echo as the first communications

satellite. It would not have been very useful, as you couldn't have much bandwidth and the signal would be weak, but it would allow them to prove the concept. Because of this, they used two Bell Laboratories inventions. One was a liquid helium-cooled pre-amplifier that was the lowest noise receiver available, and the other was a large 20-foot horn-reflector antenna that Art Crawford was project manager on, which had the advantage of not picking up noise from around it, especially Earth. Echo was launched and used to relay President Eisenhower's voice. Later, Telstar was the first actual communications satellite, the one they had really wanted to do. It was launched in 1962, and the 20-foot horn reflector was reconfigured to 4GHz to receive Telstar's signals.

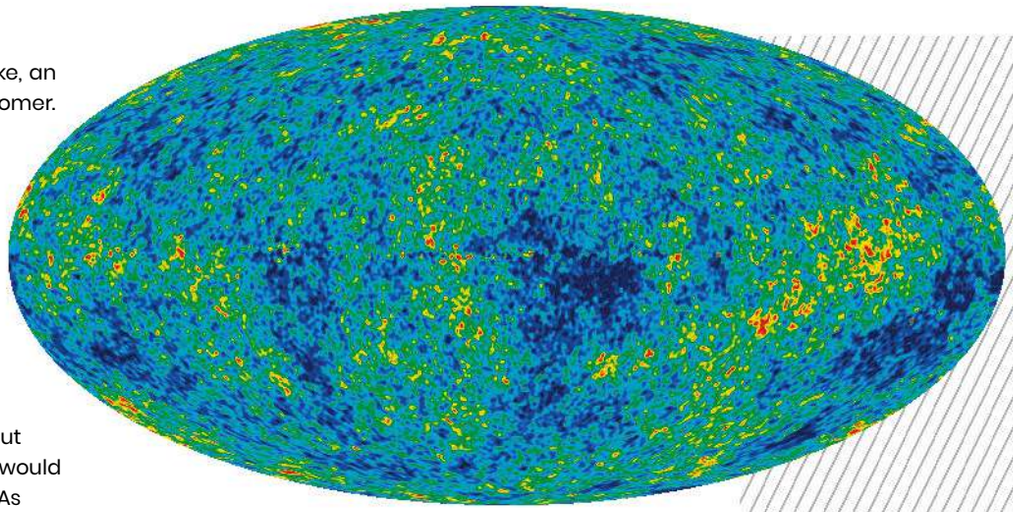
How did the communications technologies Bell Labs were working on come to be used for radio astronomy?
After finishing my Ph.D. in radio astronomy at Caltech, I took a job at Bell Labs, where the horn antenna was located. Arno Penzias had been hired the year before. So why did Bell Labs hire two radio astronomers? I think they saw three reasons. One is that radio astronomers know about looking through the atmosphere, making measurements and using large antennas, so we were useful for communication satellites. Another reason is that they were very proud of the 20-foot horn antenna and wanted to see it used for more than just one satellite experiment, so they thought that by hiring a couple of radio astronomers, more use would be made of it. I think the third reason is that Karl Jansky's discovery had not been followed up properly, and there was still the institutional memory that it should have been. The attraction for me was the research atmosphere, the generous support that was available and the opportunity to use the 20-foot horn reflector and very low noise amplifiers. We knew there were special things that could be done with the horn reflector. It was mounted so that it could see anywhere in the sky and the receiver was in the 'horn' canopy so that it was very well shielded from the ground. Arno and I made some plans. The first thing was to make accurate measurements of the brightest radio sources in the northern sky. This had a dual purpose: radio astronomers normally didn't know the sensitivity of their instrument, so they would measure a standard source, look at a source they are interested in and take the ratio. So if we contribute to an accurate measurement of what one of those sources is, it would be useful.

Yet it turned out there was some unexplained noise in those measurements.
The measurements were a disappointment and had more noise coming out of the antenna than it should have: an excess 3.5 degrees that always showed up. Any time we were looking at somewhere other than our source, it went down to that level and not any lower. We considered everything we could think of – this thing was ruining our chances to do science! Radio astronomers thought the atmosphere was contributing twice as much as we thought it was, but we had a sensitive instrument that was ideal for measuring the atmosphere, so we were confident in our measurement there. We turned our antenna and scanned around New York and all of New Jersey, and there was nothing there. There were a couple of pigeons, and they did what pigeons always do, so there was a lot of 'white dielectric material' inside our antenna.

Robert Wilson (and Arno Penzias. They shared the 1978 Nobel Prize for Physics



Dark matter is thoughts to have first formed after the Big Bang



Wilson's discovery left its mark on the world

When did the breakthrough come?

One day in 1965, Arno made a call to Bernie Burke, an older and somewhat more distinguished astronomer. Neither remembers what the initial subject of the conversation was, but at the end of the conversation Bernie asked, "How is your crazy experiment going?" Arno explained that we couldn't find any excuse for the extra noise we had and that we couldn't make it go away. As long as we couldn't understand that, we certainly couldn't look for any of the weaker sources around the galaxy. So Bernie said, "Call Bob Dicke at Princeton". Dicke was interested in the theory of gravity, which led him to think about the Big Bang. He realised that in the Big Bang it would be very, very hot and therefore full of radiation. As the universe expands, the radiation would cool and by now would probably be microwaves. He had two postdoctorate students. One of them, Jim Peebles, was put to work making calculations about what would happen in the Big Bang and to the radiation. The second, David Wilkinson, got to build a receiving system for making measurements. Jim finished first, and Jim had a request from Johns Hopkins University to give a colloquium on the subject. So Jim went off to talk about the early universe and the Big Bang and the temperature that might be left. An astronomer called Ken Turner heard it, and he told Bernie Burke. And it happened that a day or so later, Arno called Bernie.

The story told by David Wilkinson was that they were having lunch in Dicke's office. The phone rang, Dicke picked up the phone, and they heard things like 'antenna temperature', 'atmospheric radiation', 'background radiation' and 'sky temperature'. Their ears really picked up because these were the things they were interested in measuring. Dicke put the phone down and said, "Boys, we've been scooped!" We invited them over and they looked at what we had. After we had shown them our equipment, they told us about the Big Bang and the leftover radiation. Arno and I were happy to have any kind of explanation at that point, but we were both sceptical about the cosmology – it was not really explained much in those days. We wanted to leave things open, so the two groups wrote two separate papers: we wrote about our experiment and how it might be valid even if the cosmology wasn't, and they wrote about the cosmology and how it might be valid even if our experiment wasn't.

How did the news of the discovery break?

Walter Sullivan of the *New York Times* called up and wanted to ask questions about what we had done, as he had heard about our papers. The next day we were on the front page. I think Walter is actually the first person who made me think that maybe this cosmology stuff was real, and that I better learn something about it! By the end of the year, David Wilkinson and Peter Roll had made an independent measurement and confirmed what we had seen.

It turned out the theory was not new. Back in the 1940s, George Gamow and his associates Ralph Alpher and Robert Herman had been trying to work out the Big Bang and how all of creation came about in it. In 1949, Alpher and Herman wrote a paper suggesting that the temperature of the universe ought to be 5 kelvin (about -268 degrees Celsius), which is pretty good considering the crummy numbers they had to work with. Alpher and Herman had inquired about making an experiment and were told it would be impossible. So science doesn't always go along in a straightforward way.

How has cosmology developed since then?

The Big Bang was accepted. Often when there is a big paradigm shift, you have to wait for a generation of scientists to die off, but I think people were ready for a change. But as the Big Bang was fleshed out, there were a couple of nagging problems. One is the density or flatness problem. If you start off with just the right density so that space is flat, it will continue at that density as everything expands. If you change it by even the tiniest amount, if you add just one part in 10<SUP>24<SUP>, the expansion will go on for a short time and then collapse. If you take away one part in 10<SUP>24<SUP> the expansion will go so fast that stars won't form and we would never be here.

The other problem is uniformity. If we look in different directions we see essentially the same thing. And yet, in the standard Big Bang the regions where the radiation came from had never been in direct contact. So how do we solve this? In 1980, Alan Guth proposed his cosmic inflation theory. Inflation takes a tiny little space and grows exponentially in a very short time so that the density will be just right. Inflation also invokes quantum fluctuations to seed the structure of our universe. The idea is that inflation starts the whole thing, the universe expands for 380,000 years, and that's where the microwave background originated. Expansion continues to occur, and after a while there are stars and 13.8 billion years later, here we are. So it kind of looks like we understand what is happening. On the other hand, 94 per cent of the matter and energy in the universe is something we don't understand. There is dark matter and there is dark energy. I don't think we can claim we understand things until we know what is going on there.

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FOCUS ON

NASA'S DART MISSION MIGHT COMPLETELY DEFORM SMALL MOONLET

A new study finds that the spacecraft's impact could be stronger than expected

Reported by Brett Tingley

A new simulation of NASA's Double Asteroid Redirection Test (DART) mission suggests that rather than leaving a crater behind, the DART impactor could severely deform the small asteroid it will collide with. NASA's DART is an ambitious mission that will test the viability of using a 'kinetic impactor' to deflect an asteroid heading towards Earth – kinetic impactor in this case means slamming a spacecraft into the rock. DART launched aboard a SpaceX Falcon 9 rocket in November 2021 and is scheduled to arrive at its target, the binary near-Earth asteroid Didymos and its moonlet Dimorphos, in September 2022.

DART will impact Dimorphos at around 6.6 kilometres (4.1 miles) per second, which mission scientists hope will cause the moonlet's orbital speed to change by a fraction of a millimetre per second – just enough to alter its orbit around the larger asteroid. While Dimorphos and Didymos pose no threat to Earth, they are perfect candidates to test the kinetic impactor concept so that if an asteroid ever were discovered on a collision course with our planet, NASA would have a viable option for planetary defence. It's the agency's first dedicated planetary defence mission.

In the new simulation, conducted by scientists at the University of Bern and the National Centre of Competence in Research (NCCR) PlanetS, researchers were able to create a new modelling approach that accounts for the shock waves and cratering process that would follow DART's impact. Unlike previous simulations, this model took into account the fact that Dimorphos might not have a solid core, but rather a more fragmented, loosely packed one.

"Space missions demonstrate that an asteroid can have a very loose internal structure"

Sabina Raducan

This new model suggests that the DART mission could eject more material from Dimorphos than expected and potentially alter its course much more strongly than in previous estimates. "Contrary to what you might imagine when picturing an asteroid, direct evidence from space missions like the Japan Aerospace Exploration Agency's (JAXA) Hayabusa2 probe demonstrate that an asteroid can have a very loose internal structure – similar to a pile of rubble – that is held together by gravitational interactions and small cohesive forces," study lead author Sabina Raducan, a postdoctoral researcher at the University of Bern, said. "This could drastically change the outcome of the collision of DART and Dimorphos."

THE DOUBLE ASTEROID REDIRECTION TEST

1 What is DART?
The aim of the Double Asteroid Redirection Test (DART) mission is to slam into an asteroid and assess the effect on that object.

2 First impact
Testing the potential for planetary defence, DART will be the first time humanity has slammed an object in space with a kinetic impactor.

3 The target
DART's target will be the double asteroid Didymos, comprised of a 780-metre (2,550-foot) primary object and a 160-metre (525-foot) 'moonlet'.

4 Why Didymos?
Didymos has been selected for the DART mission because of its similarity to the asteroids that tend to threaten an impact with Earth.

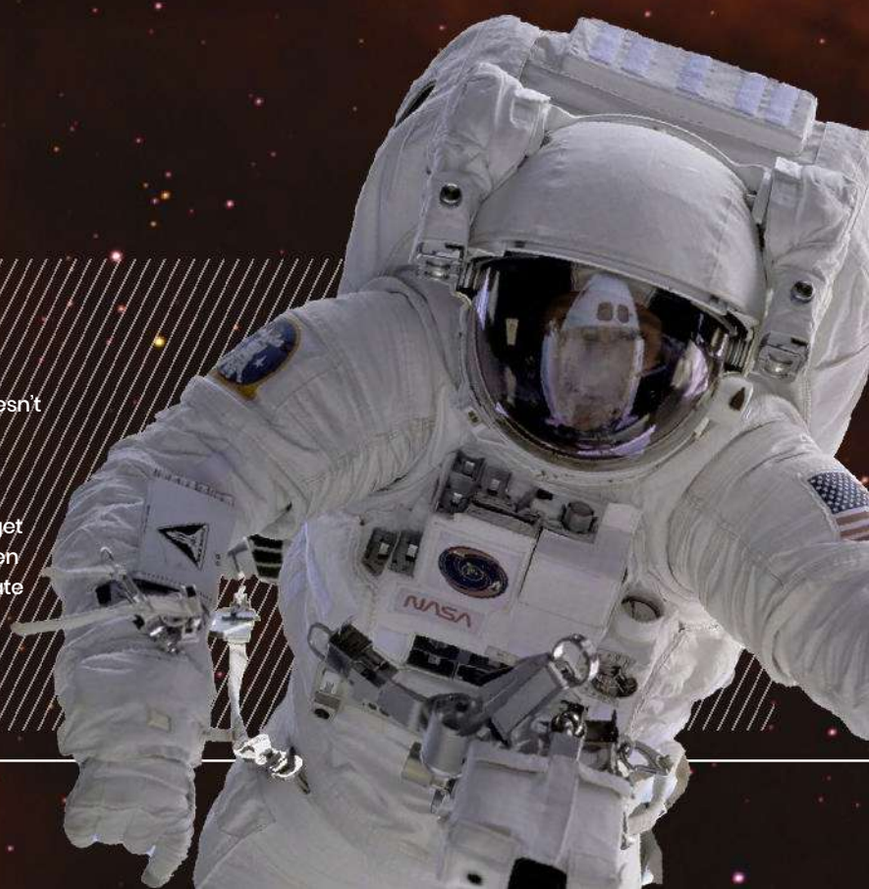
5 Dart mission launch
DART launched aboard a SpaceX Falcon 9 rocket in November 2021. It will intercept Didymos in September 2022.

© NASA

20 AMAZING FACTS ABOUT THE UNIVERSE

From the size of hypergiant stars to the weird effects of space travel on the human body, prepare to have your mind blown by the awesome cosmos we live in

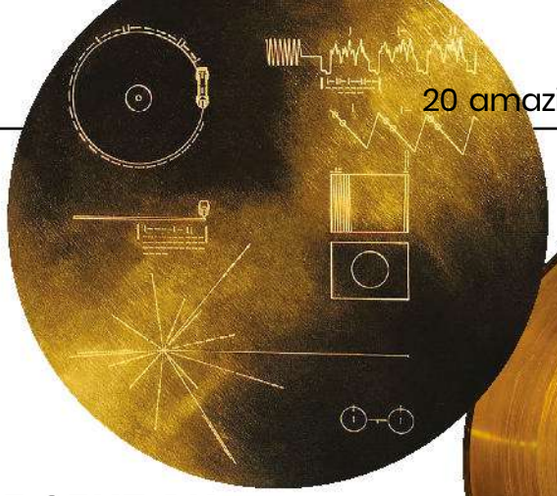
Written by Luis Villazon



1 YOU CAN'T BURP IN SPACE

Without gravity, the air you swallow with your food doesn't separate out from the solids and liquids – it just floats in a jumbled clump in your stomach. The valve at the top of the stomach normally reacts to pressure from gas and opens to release a burp. In space, what you get instead is a 'wet burp'. This feels like something between acid reflux and being a little bit sick. As if to compensate for this, the general relaxation of sphincter muscles means that astronauts fart a lot more.

© NASA; Getty



2 WE SENT AN INVITATION TO ALIENS

The Voyager probes were launched in 1977 to study Jupiter and Saturn, but their trajectory allowed them to continue past this point and head for the outer Solar System and beyond. On the off chance that either of them encounters an alien civilisation, the two probes each carry a message from Earth. The Pioneer 10 and 11 probes launched in 1972 and 1973 respectively carried a simple gold-plated plaque with some diagrams, but the Voyagers had something much more sophisticated. An analogue record, similar to a vinyl LP but made of gold-plated aluminium, was used as a time capsule to tell aliens about life on Earth. As well as spoken greetings in 55 languages, the records include sounds of music, surf, wind, bird calls and whale song.

More impressively, the records contain images as well. Before the invention of the LaserDisc and more than 20 years before DVD, the Voyager records used an analogue audio signal to encode 115 images at a resolution roughly equivalent to standard-definition TV. The images begin with diagrams that explain our system of numbers and gradually build to explain chemistry, human anatomy and biology and eventually our culture, science and engineering. Although the system for recording images on the discs was state-of-the-art for its time, an even bigger challenge was to devise a way of explaining to an alien civilisation how they should retrieve this information. Weight restrictions made it impractical to include complete playback equipment, so the Voyager probes only carried the records, with a stylus cartridge positioned at the start of the first track. A series of diagrams on the protective covers are intended to explain how they work using principles that would be applicable anywhere in the universe.

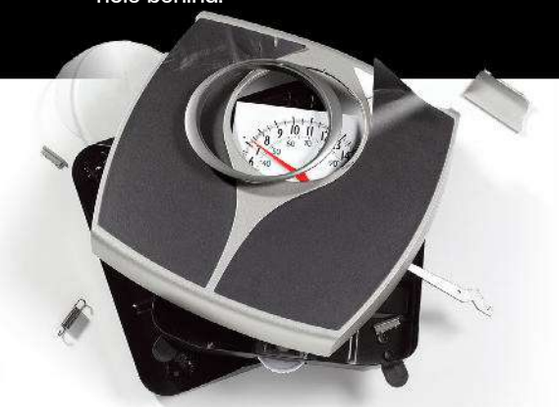
3 A TELESCOPE IS A TIME MACHINE

Light travels at almost 300 million metres (980 million feet) per second, but distances to the stars are so unimaginably vast that the light from them takes many years to reach us. Like receiving an out-of-date newspaper in the post, this means that our view of the stars is a picture of how they used to be. The more powerful your telescope, the further away you can see, and therefore the further into the past you can see. The light reaching us from the Andromeda Galaxy was emitted 2.5 million years ago. The light from the brightest quasar, 3C 273, is 2 billion years old and shone when the only life on Earth was bacteria.

4 THE LARGEST KNOWN STAR IS 1,700 TIMES THE SIZE OF THE SUN

Our Sun is brighter than 85 per cent of the stars in the Milky Way and is the fourth-heaviest among its 50 nearest neighbours, but it's a minnow compared to some. The larger a star is, the faster it burns through its available fuel. The largest known star in the universe is UY Scuti, which would engulf the orbit of Saturn if it replaced the Sun. This star will explode in a hypernova within the next 100,000 years, leaving a huge black hole behind.

Estimated number of times bigger than the Sun



5 YOU WEIGH DIFFERENT AMOUNTS ON OTHER PLANETS

Although your mass, or how much force it takes to accelerate you, is the same wherever you are in the universe, your weight, or the downward force from gravity, depends on the size of the planet you are standing on. The more mass a planet has, the more it pulls you down onto the surface.

Mercury	29 kilograms
Mars	29 kilograms
Uranus	68 kilograms
Venus	70 kilograms
Earth	76 kilograms
Saturn	81 kilograms
Neptune	86 kilograms
Jupiter	180 kilograms

6 NEUTRINOS ARE PASSING STRAIGHT THROUGH YOU RIGHT NOW

Neutrinos have no charge and almost no mass. This means that they barely interact with ordinary matter. Neutrinos are emitted by all stars, and 10 trillion neutrinos from the Sun pass through you every second. Even a lead shield a light year thick would only block about half of these neutrinos. There are three different types of neutrino – electron, muon and tau – which oscillate between each other as they travel. Astronomers hope to use neutrino detectors to 'see' distant parts of the universe currently obscured by dust and gas.

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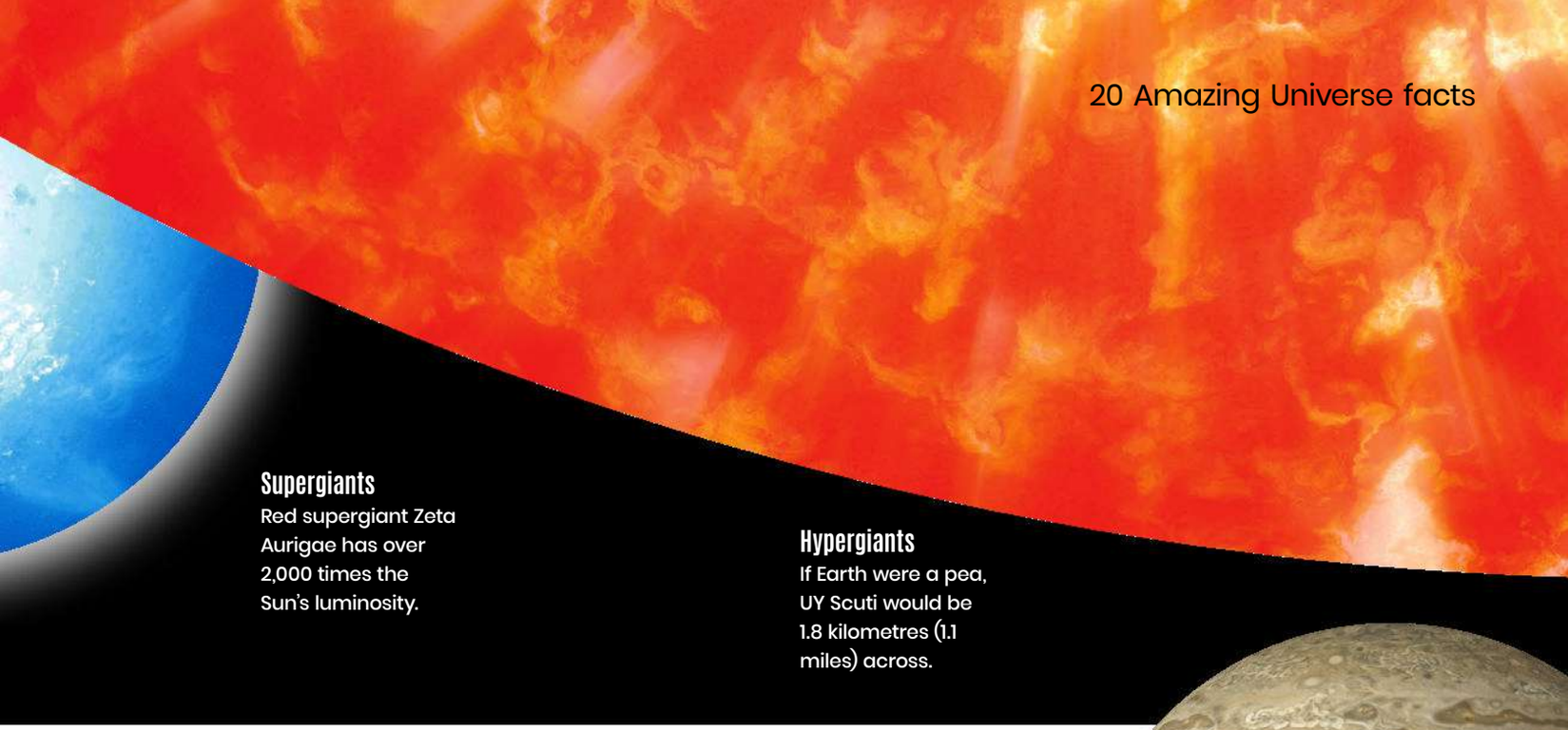


Supergiants
Red supergiant Zeta Aurigae has over 2,000 times the Sun's luminosity.

Hypergiants
If Earth were a pea, UY Scuti would be 1.8 kilometres (1.1 miles) across.

7 JUPITER IS HEAVIER THAN ALL THE OTHER PLANETS COMBINED

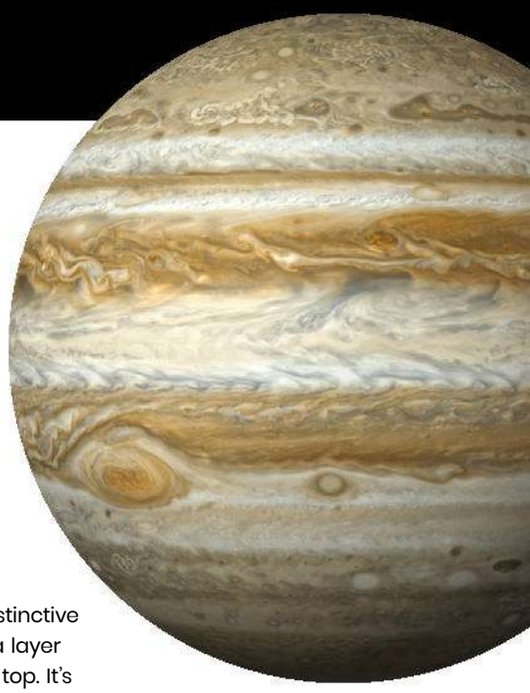
Jupiter is the largest planet in the Solar System by a large margin. It's so heavy that Jupiter doesn't orbit the Sun – the Sun and Jupiter orbit each other around a common point called the barycentre, which lies 47,000 kilometres (29,000 miles) above the surface of the Sun. Jupiter is 318 times more massive than Earth, but its volume is even bigger – there's room for 1,321 Earths within it. Jupiter is actually just about as large as a planet of its composition could be. If the gas giant gained any more mass, it would start to shrink under its own gravity. Although it would need to gain 75 times as much mass to actually initiate sustained nuclear fusion and become a star, Jupiter is still big enough to generate a lot of heat from the gravitational energy of the layers of compressed gas within it. Jupiter actually radiates more heat than it receives from the Sun.

Jupiter is classified as a gas giant along with Saturn, Uranus and Neptune. The bulk of the planet is made up of hydrogen, with 10 to 30 per cent helium and a small amount of heavier elements. This is very similar to the composition of the cloud of primordial gas that originally formed the Solar System. Jupiter was formed as a bubble of this primordial cloud that broke away from the main mass that shrunk inwards to become the Sun.

As you descend through the atmosphere of Jupiter, the pressure and temperature steadily increase until at 9,700 degrees Celsius (17,500 degrees Fahrenheit) the hydrogen becomes more like a liquid metal. But there isn't a hard boundary between the atmosphere and this metallic sea, the density just progressively increases. At the heart of the planet there may be a solid rocky core which is about 12 to 45 times the size of Earth. This could have been the initial seed that allowed Jupiter to attract gas around it during its early formation. The exact composition of the core isn't known, however, and current gravitational measurements aren't accurate enough to be sure that the core hasn't just been dispersed through the liquid body by convection currents.

Although Jupiter has the largest atmosphere in the Solar System, the distinctive pattern of stripes and spots occurs in a layer just 50 kilometres (31 miles) thick at the top. It's like the thin film of foam on the top of a cup of black coffee. It consists mainly of ammonia crystals, and the red and yellow colours are caused by ultraviolet light from the Sun reacting with phosphorus, sulphur and hydrocarbons brought up by convection currents.

The most famous is the Great Red Spot, which is an anticyclonic storm on Jupiter two to three times larger than Earth. It was first recorded in 1665, and mathematical models suggest that it may be stable enough to persist indefinitely. Beneath the ammonia cloud layer is a layer of water clouds and bubbles, and this sometimes protrudes into the upper layer to form white blobs or streaks. Because water is a polar molecule, electrical charge can build up in this layer, so Jupiter has thunderstorms with lightning a thousand times more powerful than on Earth.



Jupiter is the fourth-brightest object in the sky after the Sun, Moon and Venus

"If the gas giant gained any more mass, it would start to shrink under its own gravity"

8 A DAY ON VENUS IS EIGHT MONTHS ON EARTH

Venus spins more slowly on its axis than any other planet in the Solar System. At the equator, the surface rotates at just 6.5 kilometres (four miles) per hour. Earth rotates at 1,670 kilometres (1,050 miles) per hour at the equator. This slow rotation means it takes longer to turn on its own axis than it does to orbit around the Sun. The length of the day on most planets gradually increases over time as the gravitational pull of the Sun slows their spin, known as tidal locking, but Venus receives a separate tidal effect caused by the solar heating of its immensely thick atmosphere. Therefore the two forces cancel out and the day length is currently in equilibrium. By comparison, Earth is slowing at a rate of about an hour every 125 million years and will match the spin speed of Venus in 780 billion years, although the Sun will have died out long before then.

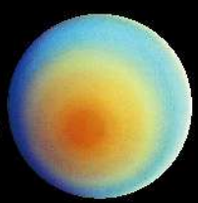
MERCURY
59*

EARTH
24**

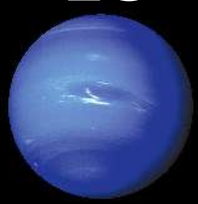
MARS
24.5**

JUPITER
10**

SATURN
10.5**



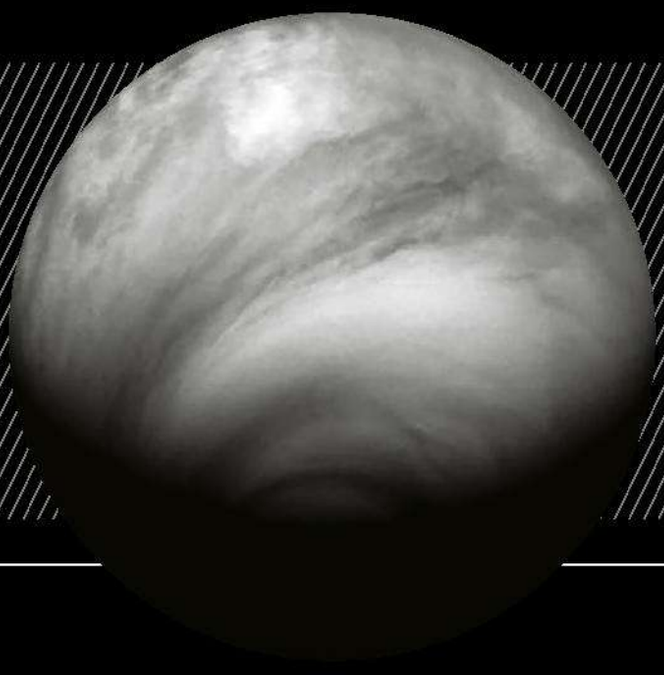
URANUS
17**



NEPTUNE
16**

VENUS
243*

* EARTH DAYS ** EARTH HOURS



9 VENUS SPINS BACKWARDS

All the planets in the Solar System orbit anticlockwise around the Sun when seen from above the Sun's north pole, and almost all of them rotate on their own axis anticlockwise as well. Venus is unusual because it rotates clockwise about its own axis. If you stood on the surface of Venus, you would see the Sun rise in the west and set in the east. This retrograde rotation means that the time between one sunrise and the next, called the solar day, is much shorter than the time to complete a full rotation, or the sidereal day, but it's still about 117 Earth days.

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10 24 MILLION METEORITES HIT OUR ATMOSPHERE EVERY DAY

Meteors are the visible trails produced by comet and asteroid debris striking Earth's atmosphere. The sudden deceleration at impact compresses and heats a bow wave of air in front of them. This heat is enough to ionise the air, causing it to glow, and also melts or shatters the meteoroid. The figure of 24 million per day is only for meteors bright enough to be visible with the naked eye. Using a telescope, that number would increase to several trillion.

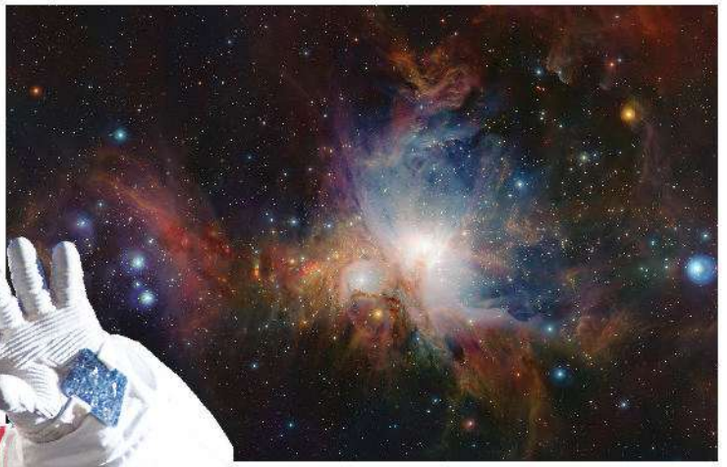
11 ASTRONAUTS GET TALLER IN SPACE

When you wake each morning, your spine is a centimetre or two longer than when you went to bed. This is because your spine relaxes when you are lying down and also because more fluid seeps into the spaces between your vertebrae. A more extreme version affects astronauts in the microgravity environment of space. Without gravity compressing their spines, they can gain five centimetres (two inches). The extra height is lost within ten days of returning to Earth, but space suits need to be designed with some slack for this.

12 THERE'S ONE ATOM IN EVERY 333 LITRES OF SPACE

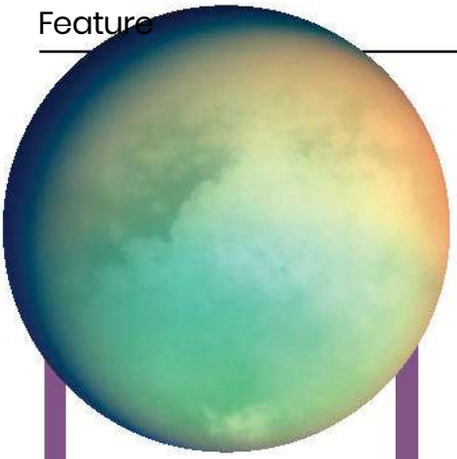
The very best vacuum chambers on Earth can generate a vacuum of less than a trillionth of an atmosphere. At this pressure, the vacuum chamber contains just 100 atoms or molecules per cubic centimetre. But in space this is a thick soup. Hydrogen clouds that are dense enough to collapse under their own gravity and give birth to new stars are less dense than this Earth-bound vacuum. The space between stars in a typical galaxy, called the interstellar medium, is about a million times less dense than that, with just 100 atoms per cubic metre, but this is still a lot denser than the universe as a whole. If you took all the matter we can see in the universe and put it in a giant blender, then tipped it back out again into a huge diffuse cloud with the same size as the present observable universe, it would have a density of somewhere between three and six atoms per cubic metre. That's 10 million times less than the best vacuum chamber on Earth.

The reason for this is that space is very big. If Earth were the size of a pea, the Sun would be a large pumpkin 118 metres (387 feet) away. The edge of the Solar System would be eight kilometres (five miles) away and the nearest star more than 30,000 kilometres (19,000 miles) away. To reach the centre of the galaxy in our tiny scale model, you would still need to travel 193 million kilometres (120 million miles). There are around 200 billion stars in our galaxy and 100 billion galaxies in the universe, but these insignificant specs of dust still leave the universe less contaminated than the purest filtered water.



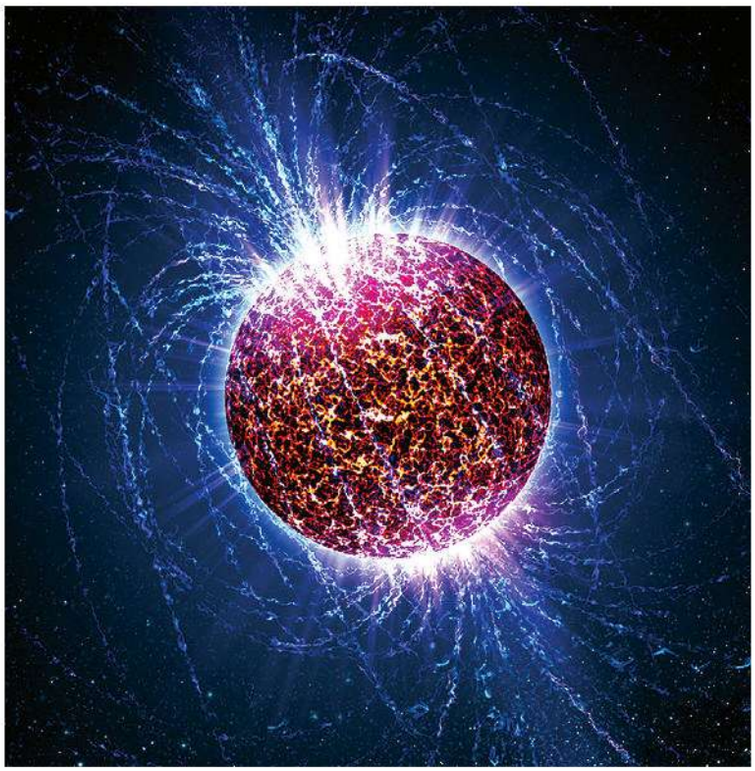
This meteor crater was formed approximately 50,000 years ago in Arizona

The universe is less contaminated than our purest filtered water



13 TRITON HAS VOLCANOES OF FROZEN NITROGEN

Neptune only gets about a thousandth of the energy from the Sun that Earth does. Its largest moon Triton is so cold that the surface is covered with frozen nitrogen snow. Despite this, it suffers from its own version of the greenhouse effect as heat from the Sun is trapped in the darker layers of water ice and solid nitrogen below. This vaporises the nitrogen, and the pressure builds up until it bursts through the crust in plumes of nitrogen gas up to eight kilometres (five miles) high that can last for a year.

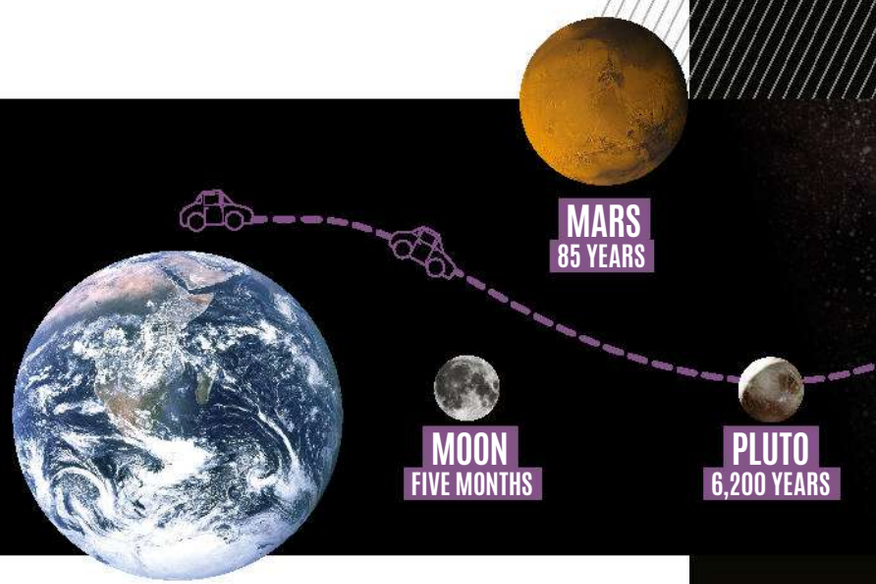


14 NEUTRON STARS SPIN FASTER THAN A KITCHEN BLENDER

When a star about twice the size of the Sun runs out of hydrogen fuel, it can't generate enough outward pressure to balance its own gravity. It collapses inward very suddenly, and like an ice skater pulling in their arms, the conservation of angular momentum causes the rotation to speed up hugely. A typical neutron star has half a million times more mass than Earth, but is only about 24 kilometres (15 miles) across. The fastest spinning neutron star, PSR J1748-2446ad, rotates 716 times a second, with an equatorial speed that's almost a quarter the speed of light.

15 IT WOULD TAKE 85 YEARS TO DRIVE TO MARS

The Moon is about 384,000 kilometres (239,000 miles) away. If you could drive at 105 kilometres (65 miles) per hour all the way to the Moon, it would take five months, and the Moon is far closer than the nearest planet. If Earth was an orange, the Moon would be a large grape about two metres (6.5 feet) away, but Mars would be a peach another 615 metres (2,017 feet) from that.



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"Solar flares release energy at all wavelengths in the electromagnetic spectrum"

16 A SOLAR FLARE HAS THE ENERGY OF MILLIONS OF ATOMIC BOMBS

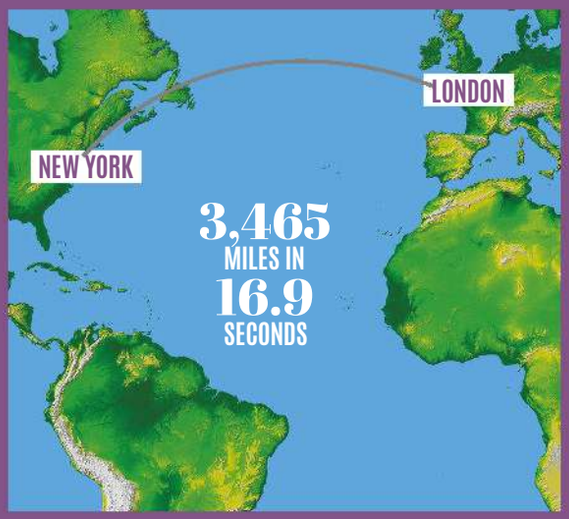
Solar flares are caused by sudden releases of magnetic energy within the Sun. This accelerates a jet of electrons, protons and atomic nuclei, which loop out from the surface of the Sun at temperatures between 10 and 100 million degrees Celsius (18 and 180 million degrees Fahrenheit). Solar flares last from a few seconds to as much as an hour and release energy at all wavelengths in the electromagnetic spectrum – from radio waves to gamma rays. The total energy is 10 million times as much as a volcanic eruption or the equivalent of millions of 100-megatonne thermonuclear bombs. This is around one-tenth of the total energy the Sun outputs in a second. The exact mechanism that triggers solar flares isn't yet very well understood, but they are more common during the active phase of the Sun's 11-year cycle.

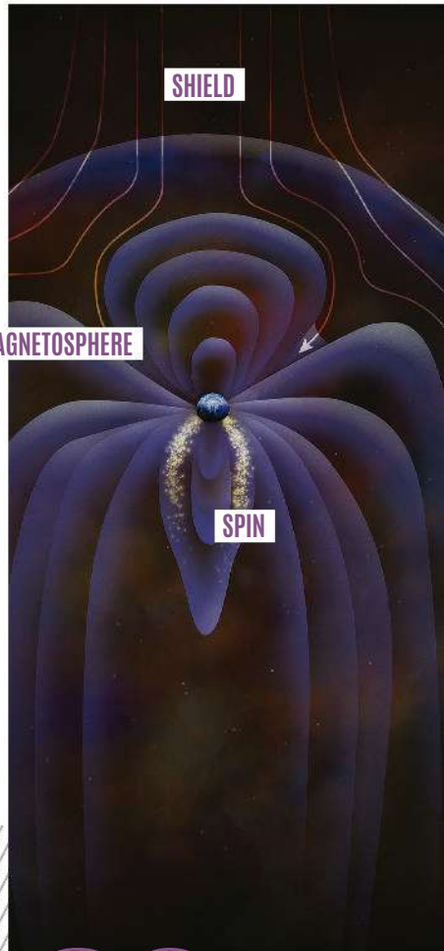
17 THE SUN'S HEART GETS VERY HOT

The enormous mass of a star means that it's always trying to collapse inwards under its own gravity. This means the pressure inside the star steadily increases towards the centre. In the core, the pressure is high enough for hydrogen nuclei to fuse into helium. This generates an outward pressure from the radiation that balances the collapse of the star. The core of the Sun is 16 million degrees Celsius (29 million degrees Fahrenheit). Larger stars can reach more than 100 million degrees Celsius (180 million degrees Fahrenheit) at the core.

18 WE'RE MOVING THROUGH SPACE AT AN ASTONISHING SPEED

In the UK, you're travelling at 1,530 kilometres (950 miles) per hour as Earth rotates on its axis. But you're also travelling at 107,000 kilometres (66,700 miles) per hour as you orbit the Sun. The Solar System in turn rotates about the centre of the galaxy, and the galaxy is part of a local cluster that's moving towards the constellation of Virgo. Put it all together and you're travelling at 330 kilometres (205 miles) per second, relative to the Virgo Cluster of galaxies.





19 THE UNIVERSE IS ONE OF THESE THREE SHAPES

Closed

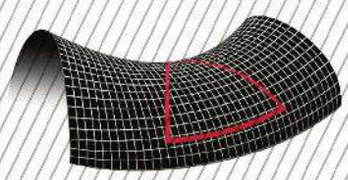
The limitations of the speed of light at large distances mean you can't really talk about 'a given moment' for far apart objects. Instead you need to think of the four-dimensional shape of space-time. The other problem is that stars and galaxies aren't just moving apart – the actual fabric of space-time is expanding. If there's enough mass in the universe to balance the force of this expansion, then the universe will halt and begin contracting again. From a 4D point of view, the universe would be closed and space-time would have positive curvature.

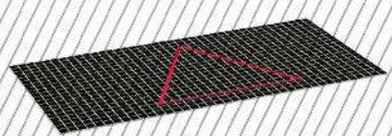
Open

If there isn't enough mass to halt the expansion, the universe will continue to expand at an accelerating rate. This would give space-time a negative curvature. In a hyperbolic universe, if you drew straight lines between three widely separated stars, the angles of that triangle would add up to less than 180 degrees. Conversely, with a closed or spherical universe, the angles of a large triangle would add up to more than 180 degrees. With tight enough curvature, we should see multiple copies of the same stars mirrored across the sky, but with different ages.

Flat

The amount of matter in the universe provides just enough gravity to halt the expansion, but only after an infinite time. In both the open and flat universe, space-time continues to expand forever. In the flat universe the rate of expansion is always slowing, whereas in an open universe it accelerates. The best measurements available to date suggest the universe is open, but only just. Models predict that the universe should be exactly flat, and it may be that the observed deviation is because we haven't found all the mass in the universe yet.





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20 PLANETS ARE HUGE DYNAMOS

The dynamo that powers your bicycle's lights works by spinning a coiled conductor within a magnetic field. This induces an electric current in the coil. Planets generate their magnetic fields using this principle in reverse. Earth's molten nickel-iron outer core is the conductor, and the convection currents cause it to behave like a coil. As Earth spins, this rotating coil generates a magnetic field that extends for 60,000 kilometres (37,000 miles) and protects the atmosphere from the solar wind. Mars lost its magnetic field 4 billion years ago when the planet's core solidified.

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INSTANT EXPERT

HOW MANY TYPES OF SPACE STATION ARE THERE?

The ISS is the largest and best-known space station, but it is not the first or the last in space

The first description of a space station appeared in a short story, *The Brick Moon*, written in 1869 by American author Edward Everett Hale. It is also thought to be the first description of an artificial satellite, and satellite navigation, as a 61-metre (200-foot) wide brick sphere is launched into orbit as a navigational aid. However, Russian scientist Konstantin Tsiolkovsky carried out the first scientific work on space stations in the early 20th century. Slovenian scientist Herman Potočnik then put forward the classic rotating ring-shaped design in his 1929 book, *The Problem Of Space Travel*. Ultimately, it would be the USSR that launched the first real space station, which was Salyut 1 in 1971.

The Salyut programme grew out of studies from the 1960s for military reconnaissance stations called Almaz; they gained new priority when the US beat the USSR to the Moon and the Soviet programme searched for a new focus. Nine Salyuts were launched between 1971 and 1986, although only six succeeded in being occupied. These were all monolithic stations in that they were a single piece launched on one rocket and all were occupied for less than a year.

The addition of a second docking port to the design for Salyuts 6 and 7 meant crews could hand over, leading to the first long-duration stays in space. NASA's first space station, Skylab, was built from Apollo mission hardware and launched on the last Saturn 5 in 1973. Three missions over 1973 and 1974 saw it occupied for 171 days by nine astronauts over the three different crews. After the end of the main project, the station remained in orbit and it was considered that the Shuttle Programme might reactivate it, but it re-entered Earth's atmosphere earlier than expected in 1979.

The first large-scale modular space station, which was constructed over the course of several launches, was the Soviet – then Russian – Mir (Peace) station. First started in 1986, the last module arrived in 1996, completing a seven module, 129-tonne space station that was occupied for 4,592 days and visited by 104 people from 12 nations, including Britain's first spaceflight participant, Helen Sharman. The end of the Soviet Union brought the American and Russian programmes together and the Shuttle flew missions to Mir from 1995 until 1998, paving the way for the International Space Station (ISS) programme.

The first parts of the ISS were launched in 1998 and it has been continuously occupied since the first crew arrived in October 2000. It is the product of cooperation between NASA, Roscosmos, ESA, JAXA and the Canadian Space Agency, and is expected to be operational until at least 2024. However, it is not the only space station currently in orbit, as China's monolithic station Tiangong-1 was launched into orbit in 2011. Although it is not currently occupied by astronauts, three-person Shenzou missions visited the station in both 2012 and 2013.

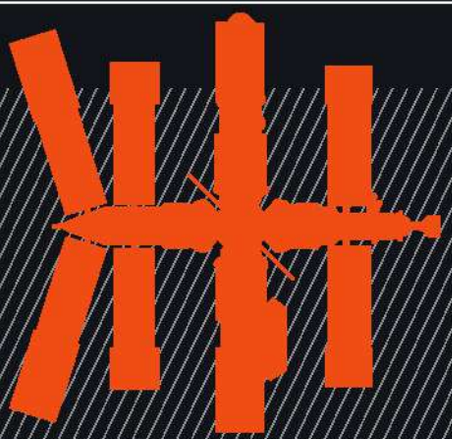
China is now planning a Tiangong-3 space station, which is due to be launched by 2022, and Russia is looking to build a new national station, constructed using Russian components of the ISS once it is decommissioned. But the US is charting new territory with the likely deployment of commercially built Bigelow inflatable space stations (based on the BEAM currently attached to the ISS) before the year 2020.

BIO

ROBIN HAGUE

Robin is a science writer, focusing on space and physics. He is the current head of launch at Skyrora, coordinating launch opportunities for Skyrora's vehicles and liaising with UK launch regulators.

ISS
Length: 73m (240ft)
Width: 108m (357ft)
Height: 20m (66ft)
Operator: NASA/Roscosmos/ESA/JAXA/CSA
Participating countries:



Mir
Length: 19m (62ft)
Width: 31m (102ft)
Height: 28m (90ft)
Operator: Soviet Space Programme/RKA
Participating countries:

Skylab
Length: 26m (84ft)
Width: 17m (56ft)
Operator: NASA
Participating country:

Salyuts 6 & 7
Length: 18m (59ft)
Width: 4m (14ft)
Operator: CNSA
Participating country:

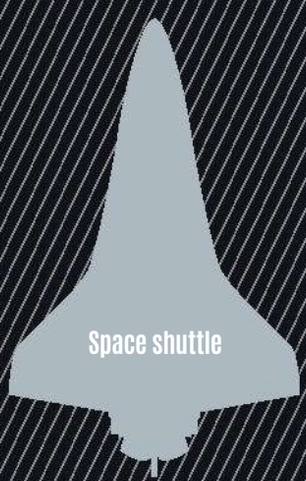
Salyuts 1 to 5
Length: 20m (66ft)
Width: 4m (13ft)
Operator: Soviet Space Programme
Participating country:

B330
Length: 17m (57ft)
Width: 7m (23ft)
Operator: Bigelow Aerospace for NASA
Participating country:

(other stations may be operated commercially for other nations)

Tiangong-3
Length: 18m (59ft)
Width: 4m (14ft)
Operator: CNSA
Participating country:

Tiangong-1
Length: 10m (34ft)
Width: 3m (10ft)
Operator: CNSA
Participating country:



Soyuz

Dragon

Russian Orbital Station
(Data only available for Nauka module)
Length: 13m (43ft)
Width: 4m (13ft)
Operator: Roscosmos
Participating country:

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USER MANUAL

MARS RECONNAISSANCE ORBITER (MRO)

THE SPECS

Launch: 12 August 2005

Launch rocket: Atlas V 401

Target: Mars

Operators: NASA and JPL

Orbital inclination: 93 degrees

Component: Multiple components

Arrival at Mars: 10 March 2006

Mission ends: TBC

Time spent in orbit: 16 years

From the fascination it has provided the field of astronomy with for centuries, to the secrets it has yielded since the first Mars mission in 1960, the Red Planet remains an elusive and esoteric point in the night sky.

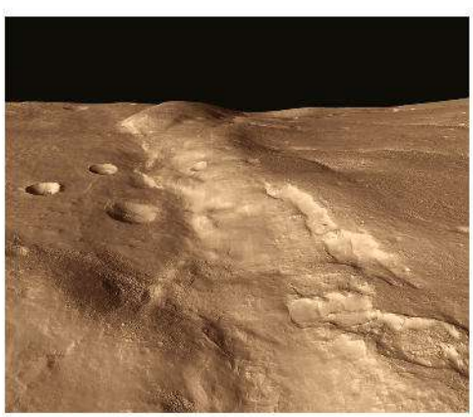
Since the early 1960s, the collective space agencies of the world have launched over 50 missions to the distant world the Romans named after their deity of war. One of those missions – NASA's Mars Reconnaissance Orbiter (MRO) – has just completed its tenth year of groundbreaking study above Mars. Through the lens of its colossal HiRISE camera, we have been able to study the Red Planet like never before and it has radically changed our understanding of this awe-inspiring destination.

Much like many spacecraft before it (and no doubt, those to come after it), the MRO was born out of NASA's ever-evolving mission to study Mars in greater depth. After more than a decade of successful launches, NASA's longstanding Mars Exploration Program (MEP) decided it needed a powerful camera, designed specifically to study Mars's unusual topography and composition.

"The Mars Reconnaissance Orbiter was designed, built and launched with the key purpose of supporting the MEP in multiple ways," reveals Dr Alfred McEwan, director at the Planetary Research Lab at the University of Arizona and a scientist involved in the MRO programme since its inception. "From the very beginning, we need it to perform the relay of surface assets, perform vital landing site reconnaissance, run important atmospheric

The MRO was launched in response to NASA's plans to study Mars more thoroughly

It took seven months for the MRO to reach Mars and enter its intended orbital insertion. This image, one of its first, was beamed back surprisingly quickly



ANATOMY OF THE MRO

The orbiter has been studying the topography and composition of Mars for 17 years, making some fascinating discoveries

1 High Gain Antenna
Theis is the Mars Reconnaissance Orbiter's main means of maintaining communication with Earth.

2 SHARAD
The MRO's onboard Shallow Subsurface Radar probes and defines the composition of Mars's polar ice caps.

3 CRISM
A visible and near-infrared tool, the Compact Reconnaissance Imaging Spectrometer for Mars measures the surface mineralogy.

4 Gimbals
Two mechanisms make sure the solar arrays point to the Sun, and another ensures the High Gain Antenna points towards Earth.

5 Solar panels
The MRO's only source of power is sunlight. Each panel is approximately 10m² (107.6ft²) and capable of generating 1,000 watts.

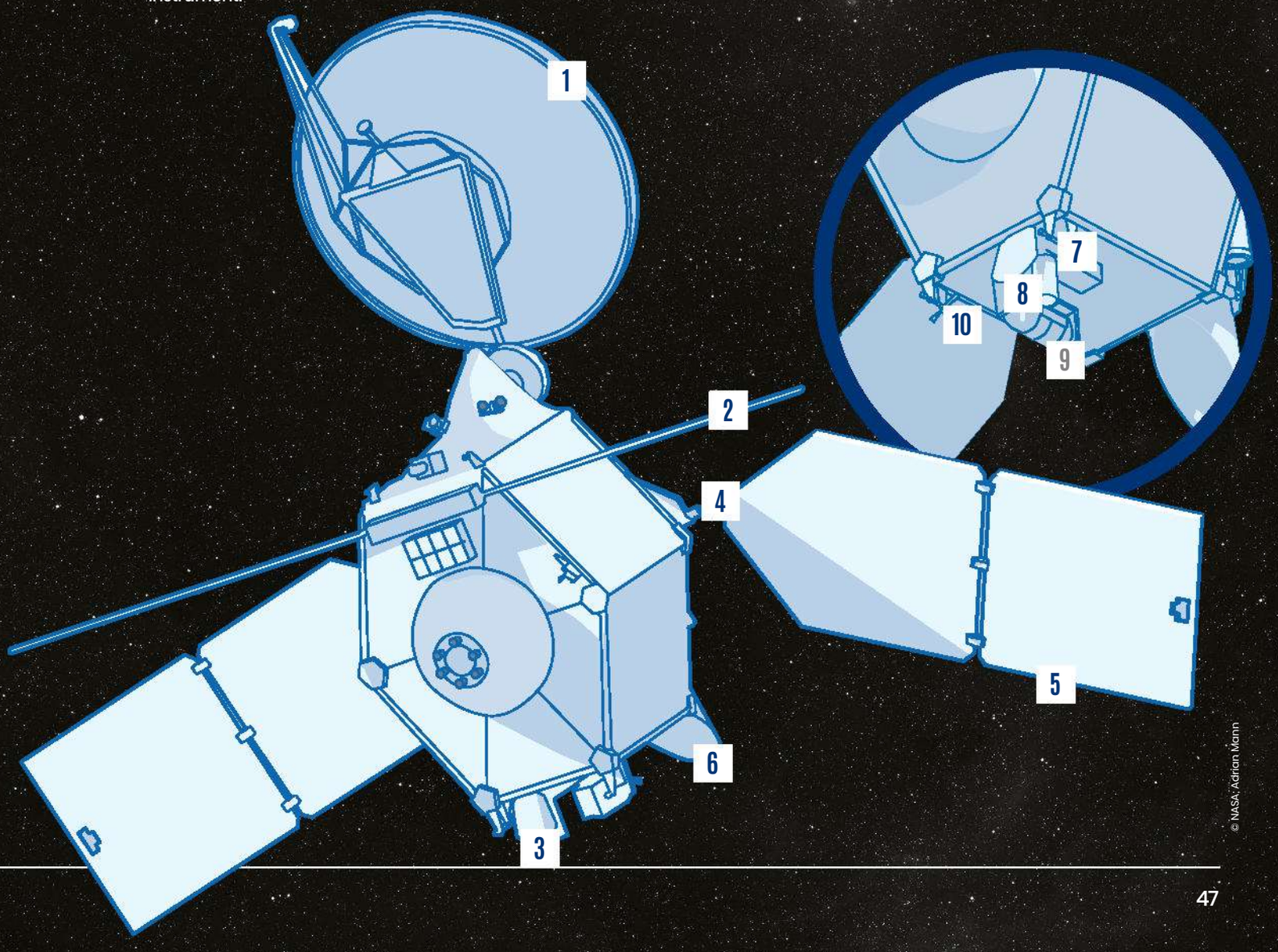
6 HiRISE
The largest and most powerful camera ever sent to deep space, the High Resolution Imaging Science Experiment is the MRO's most important instrument.

7 Electra
Electra is a UHF software-defined radio communications package used for communicating with other craft heading to and operating on Mars.

8 CTX
The Context Camera works in conjunction with MARCI and HiRISE to create large contextual maps for possible lander sites.

9 MCS
The Mars Climate Sounder is the other spectrometer on board the MRO. It measures temperature, pressure, dust levels and water vapour.

10 MARCI
The Mars Color Imager is a wide-angle, low-resolution camera that can see in five visible and two ultraviolet bands.



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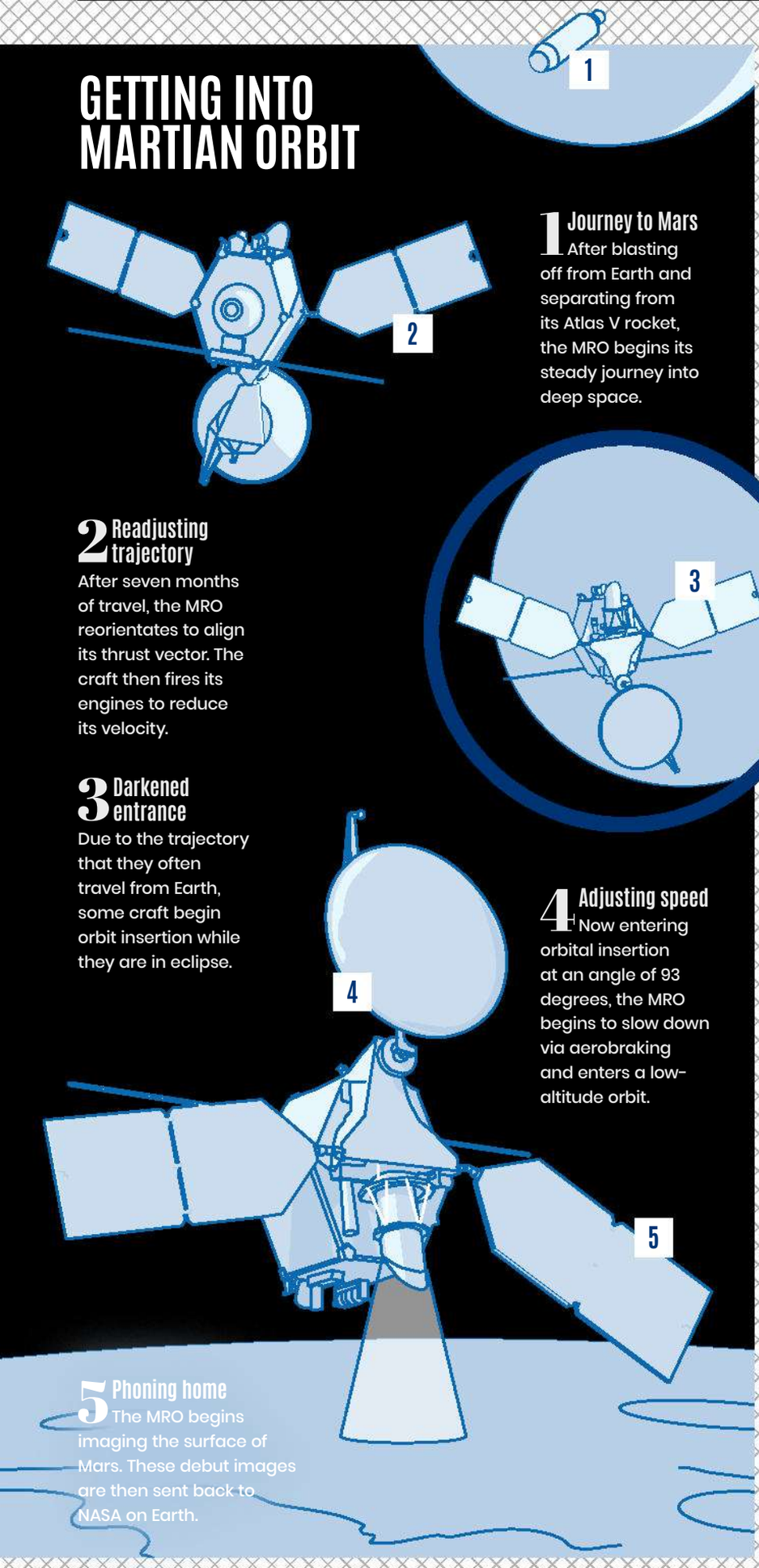
GETTING INTO MARTIAN ORBIT



1 Journey to Mars
After blasting off from Earth and separating from its Atlas V rocket, the MRO begins its steady journey into deep space.

2 Readjusting trajectory
After seven months of travel, the MRO reorientates to align its thrust vector. The craft then fires its engines to reduce its velocity.

3 Darkened entrance
Due to the trajectory that they often travel from Earth, some craft begin orbit insertion while they are in eclipse.

4 Adjusting speed
Now entering orbital insertion at an angle of 93 degrees, the MRO begins to slow down via aerobraking and enters a low-altitude orbit.

5 Phoning home
The MRO begins imaging the surface of Mars. These debut images are then sent back to NASA on Earth.

studies for EDL (Entry, Descent and Landing) and Mars-based science."

Even before it launched from Cape Canaveral in 2005, it was already turning heads, most notably for the hyperactive speed of its development. Most orbiters take around a decade from design to launch, but for the MRO, that turnaround was positively supersonic. "It was approved back in 2001 and was ready for launch in August 2005," comments Dr McEwan. "This was very fast compared to the development cycles of today's NASA."

So what makes the MRO so different from the other Mars orbiters the American space agency has launched in the past? The answer lies in the clarity of its images and the data it captures from the planet's atmosphere and composition.

"MRO has the most capable science instruments at its disposal (highest spatial resolution at visible, infrared and radar wavelengths) and a much higher data rate than any other orbiter we've ever launched," adds Dr McEwan on the craft's unique instruments. "Orbiters provide the global view and landers/rovers study very tiny areas in great detail, so in that regard they're quite synergistic in their capabilities."

The main crux of those capabilities lies in its onboard camera – HiRISE. The largest camera ever carried on a deep space mission, this 0.5-metre (1.6-foot) reflecting telescope is the grandest of three lenses pointed at Mars' surface (the Context Camera takes images in greyscale and provides context maps for the other

VITAL STATISTICS

2,000 Watts – The amount of electricity needed for the MRO

58.3M – The height of the Atlas V rocket

2,180kg – The weight of the MRO

54.6mn – Minimum distance from Mars to Earth

HEAD TO HEAD

How does NASA's MRO measure up to the other long-standing orbiter, the 2001 Mars Odyssey? In terms of launch mass, Odyssey clocked in at 725kg (1,598lb), but the MRO is far chunkier at 2,180kg (4,806lb). However, both orbiters are tiny compared to a regular double decker bus's 11,900kg (26,235lb). Height-wise, the Mars Odyssey is 2.2m (7.2ft), while the MRO is 6.5m (21.3ft) – about one and a half times the height of a double decker bus (4.38m or 14.4ft).

cameras, while the low-resolution MARCI – Mars Color Imager – gives daily Martian weather reports).

The heart of the MRO's science mission (which was only meant to last two Earth years from 2006 to 2008) is centred around mapping the planet's surface to determine ideal landing sites for future NASA landers, and studying the Martian atmosphere and landscape to better understand its composition and the nature of its aqueous deposits. Its trio of aforementioned cameras capture these maps with incredible clarity, a capability bolstered by its spectrometers CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) and MCS (Mars Climate Sounder). The MCS and the MRO's Shallow Subsurface Radar (SHARAD) have been helping NASA scientists study another fascinating aspect of Mars – the presence of water in its various aqueous forms, much of which is contained in ice caps buried in the planet's subsurface.

Using sounders and radars like CRISM and SHARAD, the MRO made a startling discovery – results published in the *Science* journal in September 2009 showed deposits of polar ice had been exposed to the surface by comet strikes. "Ice exposed (temporarily) by new impact craters was a brand new discovery made by the MRO, and there have been many advances in polar science," says Dr McEwan. "Another notable milestone is the discovery, by radar, of buried carbon dioxide ice in the south polar cap."

Now ten years into its lifespan, the MRO's future is far from grim. In fact, it's now fully embracing its role as a communications support craft for future missions. It supports the InSight Mars lander, which arrived on Mars in November 2018 and the Perseverance rover in February 2021.

> "MRO has the most capable science instruments at its disposal"
>
> **Dr Alfred McEwan**

TOP TECH

HIGH RESOLUTION IMAGING SCIENCE EXPERIMENT

The MRO's High Resolution Imaging Science Experiment is a milestone in space-based camera technology. It's the largest and most powerful camera ever sent into deep space and consists of a 0.5m (1.6ft) aperture reflecting telescope. It cost a whopping $40mn (£27.5mn) and can capture images of Mars' surface with resolutions of 30cm/pixel (11.8in/pixel). It has even caught shots of the Curiosity and Opportunity rover missions.

HOW TO...

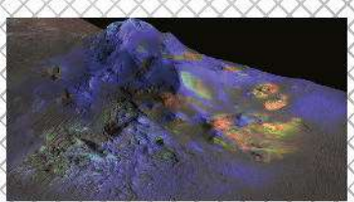
MAP THE MARTIAN SURFACE

1 Providing some context

The MRO uses the Context Camera to determine where to point HiRISE. SHARAD is used if underground polar ice caps are also factored in.

2 Capturing the spectrum

To capture the likeness of the surface, the MRO uses a spectrometer. CRISM lets the MRO map include mineralogy and composition data.



3 Global scale

Before HiRISE is put into action, MARCI begins taking wide-angle shots. It can take up to 84 images a day, creating a vast map of the Martian surface.

4 Capture and return

To capture high-resolution detail, NASA uses HiRISE. Pointed at a location based on data collected by CRISM and CTX, it beams photos back to NASA.

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FOCUS ON

GAMMA-RAY BURSTS MIGHT BE MUCH RARER THAN WE THOUGHT

Simulations of black hole birth are unlocking the secrets of these bright-light phenomena

Reported by Tereza Pultarova

The first-ever 3D simulation of the formation of a black hole jet reveals why mysterious gamma-ray bursts appear to blink and suggests that these mysterious phenomena might be much rarer than astronomers suspected. Gamma-ray bursts are the brightest and most powerful flashes of light known to exist in the universe. First detected in 1967, these blinding light explosions are generated when massive stars collapse into black holes, launching jets of material that squirt into space at nearly the speed of light.

Currently, satellites spot about one gamma-ray burst somewhere in the universe every day. But astronomers think that up to 500 may flash through the universe without us knowing every day. However, a new study suggests the actual number might be ten times lower. The study, by a team of astronomers from Northwestern University, simulated for the first time in detailed 3D the birth of black hole jets powered by collapsing stars. The simulation showed that as a massive star collapses, a black hole starts to form at its heart, surrounded by a disc of infalling material. In some cases, the material in the black hole's vicinity can be accelerated into a jet that escapes the black hole's gravitational pull. All this is happening while the nascent black hole is still surrounded by the envelope of the dying star.

"Previous studies have tried to understand how [the jets] work, but those studies were limited by computational power and had to include many assumptions," Ore Gottlieb, an astrophysicist at Northwestern University and lead author of the new study, said. "We were able to model the entire evolution of the jet from the very beginning – from its birth by a black hole – without assuming anything about the jet's structure. We followed the jet from the black hole all the way to the emission site and found processes that have been overlooked in previous studies."

To trigger a gamma-ray burst, the jet must have enough energy to crack through the collapsing star's envelope and escape into the surrounding space. "The jet generates a [gamma-ray burst] when it reaches about 30 times the size of the star – or a million times the size of the black hole," Gottlieb said. "In other words, if the black hole is the size of a beach ball, the jet needs to expand over the entire size of France before it can produce a gamma-ray burst."

The simulation revealed for the first time that as material from the collapsing star falls onto the accretion disc around the black hole, it causes this disc to tilt and wobble like a spinning top. This tilt affects the trajectory of the jet, which in contrast to previous assumptions doesn't follow a constant direct line. This wobbling of the jet explains one of the biggest gamma-ray burst mysteries – their blinking nature.

"Emission from gamma-ray bursts is always irregular," Gottlieb said. "We see spikes in emission and then a quiescent time that lasts for a few seconds or more. The entire duration of a gamma-ray burst is about one minute, so these quiescent times

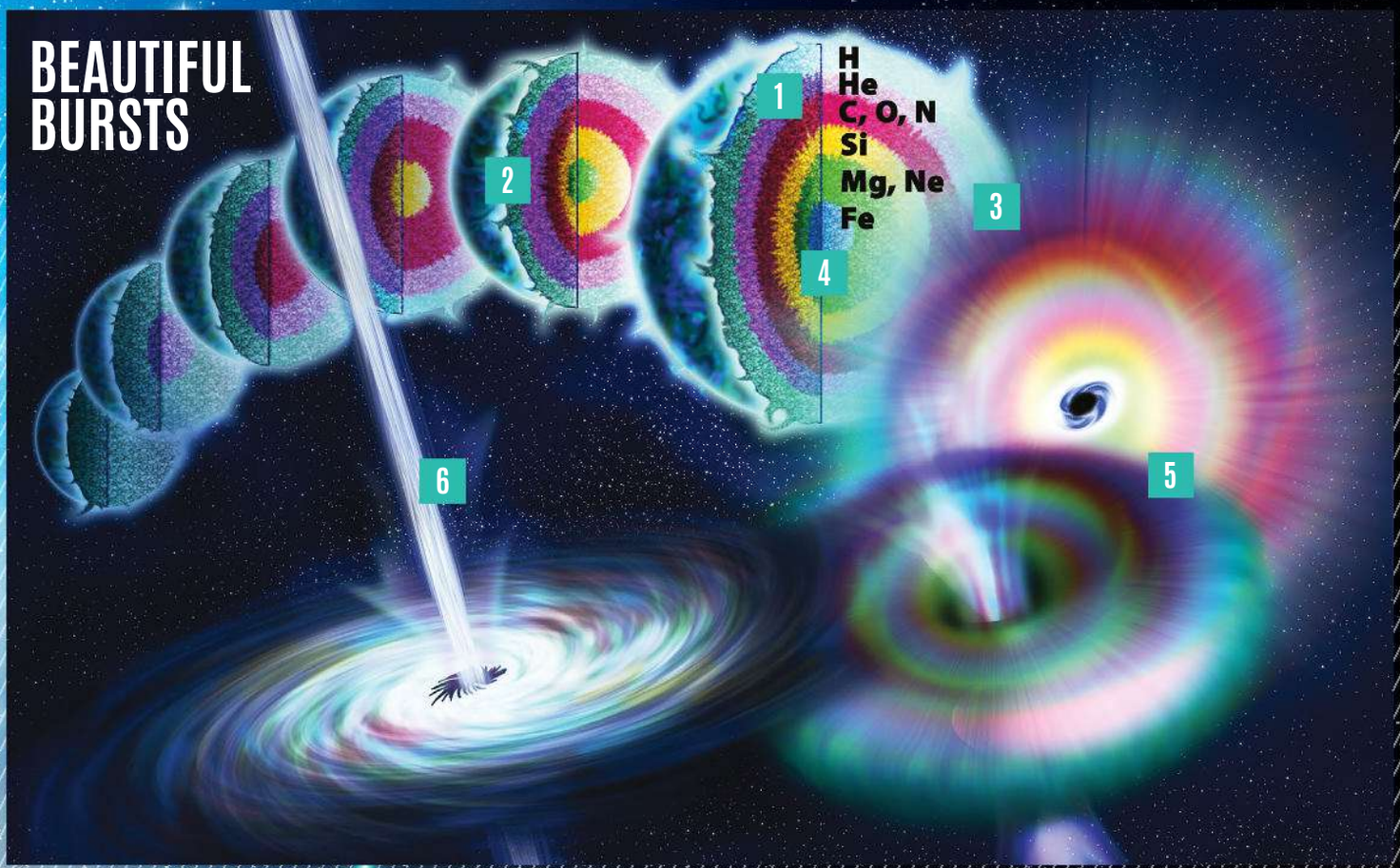
> "We were able to model the entire evolution of the jet from the very beginning – from its birth by a black hole"
>
> **Ore Gottlieb**

are a non-negligible fraction of the total duration. Previous models weren't able to explain where these quiescent times were coming from. This wobbling naturally gives an explanation to that phenomenon."

Just like the beam from a lighthouse, a gamma-ray burst is only visible to astronomers when the jet generating it points towards Earth. The wobbling of the jet, however, means that many more gamma-ray bursts can be observed than scientists previously estimated. "The observed and true rates are different because we can only see the gamma-ray bursts that are pointing at us," said Gottlieb. "That means we need to assume something about the angle that these jets cover in the sky in order to infer the true rate of gamma-ray bursts – that is, what fraction of gamma-ray bursts we are missing."

This new model suggests that the wobbling increases the observability of gamma-ray bursts up to ten times, which means that only 50 instead of 500 may be flashing through the universe on any given day. That might be good news for us on Earth, as a gamma-ray burst exploding too close to our planet would blow off a big part of Earth's atmosphere – especially the ozone layer which protects us from harmful ultraviolet radiation.

BEAUTIFUL BURSTS



1 Fusion
Stars generate energy through nuclear fusion. In massive stars it is via the carbon, nitrogen, oxygen (CNO) cycle, which act as catalysts for fusion involving hydrogen atoms.

2 Onion layers
Nuclear fusion of hydrogen creates helium. Temperatures grow so high that the helium begins to fuse to create oxygen, then nitrogen, carbon, silicon and so on.

3 Living fast
Massive stars struggle to stay aloft against the pull of gravity, so they have to generate a lot of energy, which uses up their vast stores of gas in just a few million years.

4 Iron star
Massive stars end up with cores of iron, which cannot undergo further nuclear fusion without putting in more energy than it produces. Fusion ceases in the star's core.

5 Collapse
As the massive star reaches the end of its life and is unable to generate any more energy, the core of the star begins to collapse in on itself to form a black hole.

6 Jets
Gas inside the star swirls around the black hole and forms powerful jets that destroy it. Charged particles spiralling around the magnetic jets produce gamma rays.

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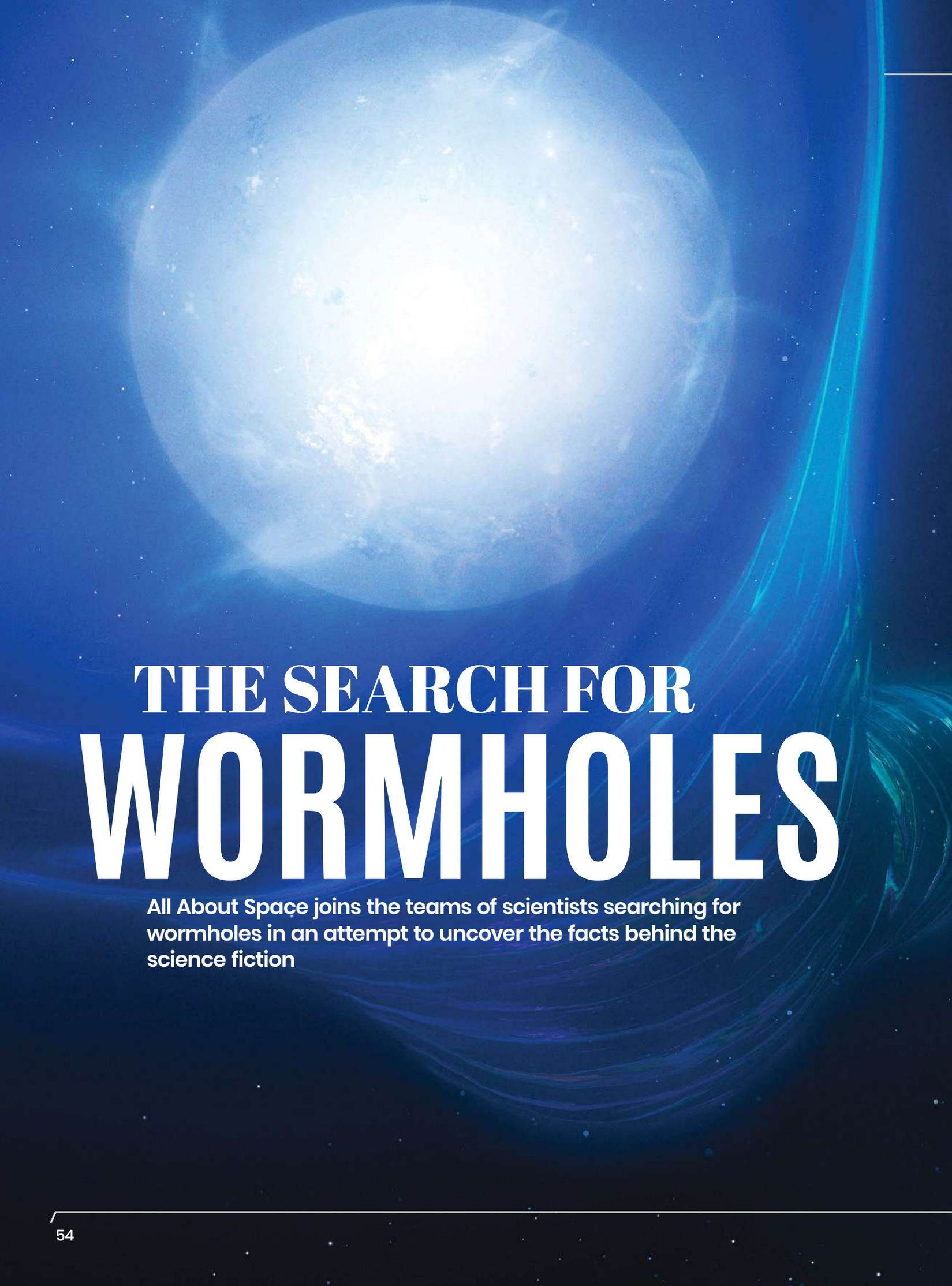


THE SEARCH FOR WORMHOLES

All About Space joins the teams of scientists searching for wormholes in an attempt to uncover the facts behind the science fiction

Wormholes are so-called gateways that provide a shortcut through the fabric of space-time. They can be thought of as tunnels with ends capped by an ever-hungry black and a white hole, the black hole's time-reversed cousin that prefers to spit things out if anything comes too close to its event horizon.

It's true that a wormhole never looks out of place in science fiction – for example, lurking in the universe of *Star Trek: Deep Space 9* and employed by captain Benjamin Sisko and his crew of the Defiant. They use the hole to travel from the Alpha to the Gamma quadrant on the other side of the galaxy at unprecedented speed – certainly a thrilling prospect.

However, we still don't know for sure whether traversable wormholes like the ones in *Star Trek* really exist. Even finding the slightest hint of these natural portals almost seems like a pipe dream. With this in mind, it would seem odd that massive organisations are still looking, such as Project RadioAstron, the Soviet Union's first radio astronomy research facility.

"The search for wormholes seems like a worthy undertaking," muses assistant professor of astrophysics Robert Owen of Oberlin College. His thoughts are echoed by Igor Novikov, a Russian theoretical astrophysicist and cosmologist who made an important contribution to the theory of time travel during the mid-1980s. The Novikov Self-consistency Principle states that it's impossible to make paradoxes of time. "There's a hypothesis that primordial wormholes exist and can connect some regions in our universe in the model of the multiverse," Novikov, who is based at the Russian Space Research Institute in Moscow, explains. "In this case, the search for astrophysical wormholes is a unique possibility to study the other universes."

These elusive tunnels through space wouldn't just be a major discovery in and of themselves, but could even open up avenues to bigger things – possibly even answering some of the deepest questions about the nature of our universe. Although we haven't found them yet, the laws and complex equations that underpin Einstein's theory of general relativity say that technically they should exist out there somewhere – maybe as microscopic structures the size of atoms, or giant but impassable wormholes connecting the black holes in the centres of galaxies. However, should a stable wormhole be found, it might be possible to travel down it and end up in another place, and another time, in the universe.

> **"There's a hypothesis that wormholes exist and can connect some regions in our universe"**
>
> **Igor Novikov**

Clearly, the practicalities of finding a wormhole is a challenging subject entirely on its own, and one that scientists like Owen relish. The search wouldn't merely mean searching for the wormholes themselves, but the equally elusive white holes that are supposedly tacked onto one end, making the task of locating them all the more difficult. However, Owen believes that even in light of the obvious difficulties, the hunt for wormholes must be supported. He studies the relativistic effects of black holes and neutron stars colliding to make gravitational waves – ripples in the curvature of space-time – to find traces of the holes.

So, is finding a wormhole really that important at all? **All About Space** asked theoretical physicist Kristan Jensen at the University of Victoria. Alongside Andreas Karch, a professor of physics at the University of Washington, Jensen looks at wormholes purely from a theoretical perspective. "Honestly, no," he initially answers. "I find it unlikely that there are wormholes [of notable size] in our universe." This is because he – as well as quite a few in the scientific community – believe that we might be hard-pressed to find these tunnels through space. Paradoxically, it seems that the theory suggesting that wormholes exist also makes an equally strong case for how they could never be real.

If you were to open up a wormhole, you might find it quickly begins to fall apart.

Egyptologist and linguist Daniel Jackson, the protagonist in *Stargate*, might have found himself cautiously stepping into a stable wormhole when he cracked the code behind the hieroglyphics that opened a pathway to another galaxy. The reason that we might not be able to find a wormhole could simply be that in reality they're incredibly unstable entities.

Owen suggests that you just need to think about travelling through one to get a full picture of why this is. "In general relativity, time travel is actually one of the things that naturally comes along with wormholes," he says. "However, the idea that wormholes could be used for travelling through time is usually taken as an indication that they probably couldn't exist." Owen references several calculations that have been processed, showing that wormholes naturally destroy themselves before they could even offer us the chance to be used to travel back in time. "Imagine that I had a wormhole with both throats [in other words, both openings to the wormhole], in my office and I could step into one of them and emerge from the other ten seconds earlier," he describes. "For those ten seconds there would actually be two of me in the office. But what if I then chose to wait those ten seconds and then step through [the black hole again], simultaneously with my earlier self?" The answer is that Owen and his past self would again emerge from the white hole ten seconds earlier and there would now be three of him. "If I did it again, there would be four of me, five, six and so on," he continues. "This silly story illuminates the way that a wormhole would naturally destroy itself."

Owen is talking about feedback, just like the feedback you might get on a microphone, because it's not just people that could take a trip though these time-tunnelling wormholes. Radiation, be it light or heat, can also enter the wormhole and do exactly the same thing as the multiple Robert Owens. So much energy would end up in the loop that it would cause the wormhole to collapse.

Another problem is that a wormhole would be too small for a single person – let alone a spaceship capable of interstellar travel – to be able to comfortably fit through. To successfully pass through a hole, we would need to find some way of enlarging one, something that seems unfeasible given that we don't even yet have proof of its existence.

However, not everyone thinks that the journey would be impossible. One of the world's leading theoretical physicists, Kip Thorne, is professor emeritus at the California Institute of Technology (Caltech) and a long-time friend of both the late Stephen Hawking and Carl Sagan. Thorne not only thinks that these portals might exist, but that they could also be used as some kind of time machine, capable of getting us from one place in the universe to another.

Another scientist who has confidence in the possibility of using wormholes for travel is Eric Davis, a senior research physicist at the Institute for Advanced Studies at Austin, Texas. "All you need to enter a wormhole is a spacecraft. Just dive in and go," he says. "If the wormhole is too small for a spacecraft, then it has been posited by Kip Thorne, the man who discovered suggestions of traversable wormholes in Einstein's theory of general relativity, that all one may need to do is feed the wormhole more negative energy density and/or more-negative pressure to inflate it up to a larger size."

So, what is negative energy? Dark energy, which is causing the universe to expand, is an example of a negative energy pressure

WHY ARE WE LOOKING FOR WORMHOLES?

Professor Robert Owen, of Oberlin College, USA, tells us why hunting for wormholes is so necessary

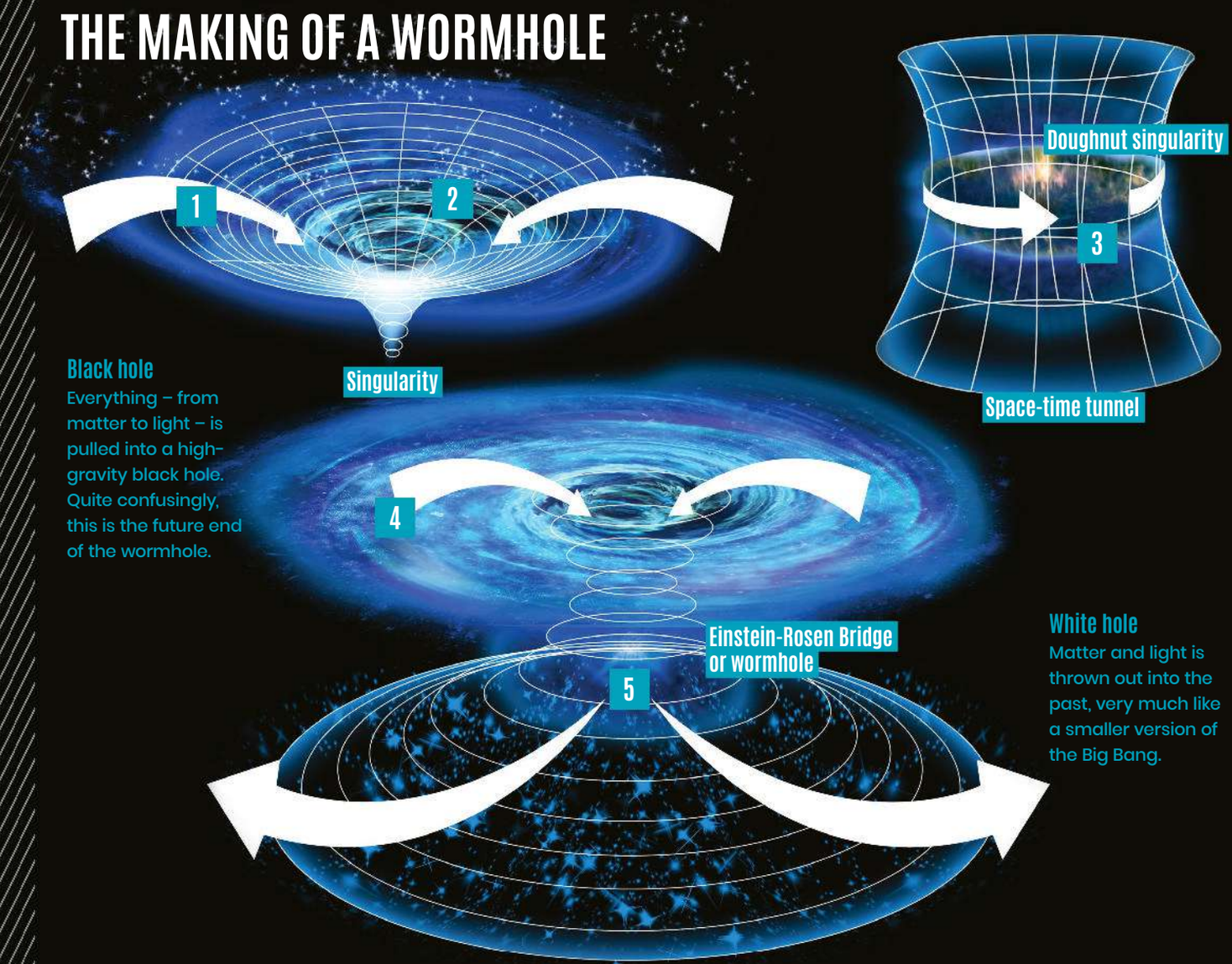
"I think it's extremely important that we continue to search for and research the ideas behind wormholes. There are all sorts of [avenues for] research and we often find that some subjects are more practical than others. Obviously wormhole physics is not a very practical subject, but wormholes and other exotic phenomena provide a route to understanding some of the deepest questions about the nature of our universe. For that reason alone, this is an exciting endeavour and deserving of support.

"It's also important to note subjects that might seem highly impractical could eventually be central to our daily lives. Electromagnetic theory was at one time considered an impractical subject and now it's fundamental to everyday life. Quantum theory has long been viewed as an arcane body of research, but now it's essential for the inner workings of much modern technology.

"All research is fundamentally interconnected, with insights made in one field of study often transferred. For example, there is a long-standing symbiosis between research in particle physics and solid-state physics – the field that provides much of our understanding of the properties of materials. There is a constant conversation between these two fields of study and ideas are regularly shared between them.

"Einstein's general theory of relativity predicts quite clearly that if a wormhole existed, it would be unstable and we wouldn't be able to use it for travelling through time. However, with all scientific questions, we can't be completely certain that general relativity is the most accurate possible description of space-time in all situations. It could be that in certain situations general relativity becomes inaccurate, just as Newtonian physics becomes inaccurate near a black hole, for example. This means I certainly wouldn't rule out the idea absolutely, until we have some good astronomical evidence."

THE MAKING OF A WORMHOLE



Black hole
Everything – from matter to light – is pulled into a high-gravity black hole. Quite confusingly, this is the future end of the wormhole.

White hole
Matter and light is thrown out into the past, very much like a smaller version of the Big Bang.

1 Collapse of the core

When a gigantic star dies, when it no longer has any nuclear fuel to burn, sometimes a black hole is formed. The core has no choice but to collapse in on itself in the catastrophic explosion of a supernova. The devastated star's outer layers are expelled into space, while the core continues to shrink in size.

2 A cosmic plug hole

Shrinking smaller and smaller, the core continues to pale in significance. While it has shrunk to a speck, all of its mass is concentrated in a very small area. This forms a singularity. If you place anobject onto a bed sheet, it makes a dent. Anything moving towards the dent will fall towards it, which is how gravity affects the universe.

3 The makings of a doughnut

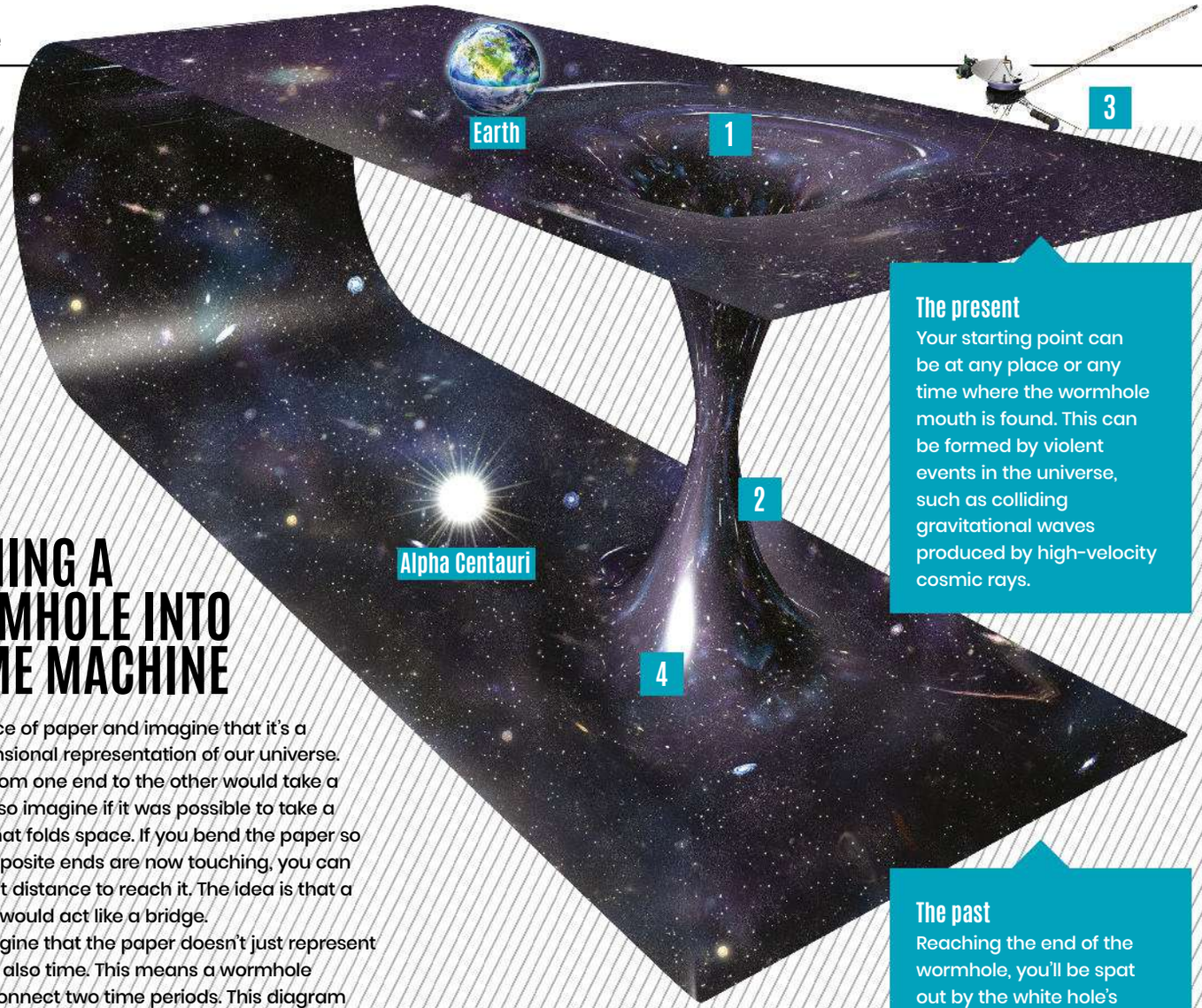
A star's core can still be found to be spinning when it decides to collapse. Crumbling to a singularity, it rotates faster and faster, spinning so fast that what's left of the star's material spreads out. Space-time is no longer focused on a single point, but is being wrapped around space ring.

4 Punching through space

The tunnel punches its way through the fabric of space-time and, almost in an unusual state of reversal, emerges backwards in time and into the past. This tunnel, which can work its way into another parallel universe, is called an Einstein-Rosen bridge, or wormhole. Any matter grabbed by the black hole is passed through t his tunnel.

5 Exit

If you were to travel through a wormhole, you would reach its far side, which can be likened to a black hole in reverse: the white hole. Matter pulled in by the black hole will emerge from the singularity found at the white hole's centre and released.



TURNING A WORMHOLE INTO A TIME MACHINE

Take a piece of paper and imagine that it's a two-dimensional representation of our universe. To travel from one end to the other would take a long time, so imagine if it was possible to take a shortcut that folds space. If you bend the paper so the two opposite ends are now touching, you can hop a short distance to reach it. The idea is that a wormhole would act like a bridge.

Now imagine that the paper doesn't just represent space, but also time. This means a wormhole can also connect two time periods. This diagram illustrates exactly how this could be possible.

1 Enlarging the mouth

To enlarge the mouth, you would need exotic matter – in other words something with negative energy to act as an anti-gravity to hold the

2 The throat

Between the two mouths of the wormhole is a throat that acts as the bridge across space and time.

3 The traveller

Stable and traversable wormholes would need to be big enough for a person or a spaceship to travel through them.

4 Mouth of the wormhole

Scientists call this a closed time-like curve – a loop that connects the two different periods of time found at each mouth of the

The present

Your starting point can be at any place or any time where the wormhole mouth is found. This can be formed by violent events in the universe, such as colliding gravitational waves produced by high-velocity cosmic rays.

The past

Reaching the end of the wormhole, you'll be spat out by the white hole's event horizon. On this side you would have travelled both backwards in time and onto the other side of the universe – if you're even in the same one you started in, that is. Estimations of where a wormhole could take you are beyond even our best theories at present.

– something that is opposing forces such as gravity. However, we don't even know what dark energy is, let alone how to create true negative energy, so we won't be venturing down a wormhole any time soon.

Still, this isn't to say that nature hasn't found a way to enlarge wormholes, which is exactly what Russian scientists working on Project RadioAstron are banking on. They are using the largest space telescope ever launched – not Hubble or the Herschel Space Observatory, but Spektr-R, a radio telescope that launched into space in 2011 and has a detector diameter of ten metres (33 feet). The hope is Spektr-R will discover evidence for wormholes and white holes.

The project's initial steps into probing the universe were originally quite bleak, because the Soviet Union collapsed just as it was within reach of being completed, but now it has been restarted. Until quite recently an old radio telescope built in 1959, dubbed RT-22, was the main receiver of signals from the Spektr-R. For many months the receiver has been studying supermassive black holes found at the centres of galaxies and even probing the Milky Way's own black hole, Sagittarius A*. Observations of the black hole's event horizon – the point of no return from this exotic high-gravity beast – is where RadioAstron's aims get interesting.

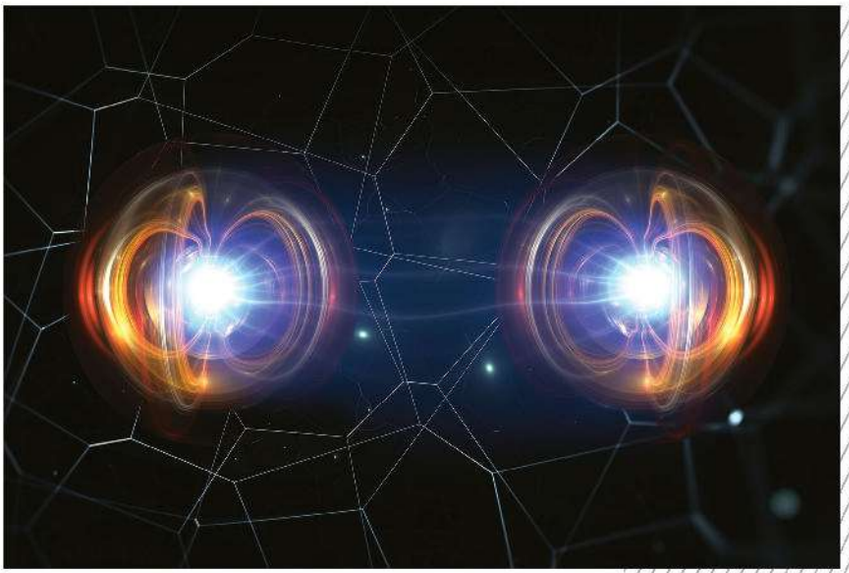
Getting close to black holes could lead us to the elusive wormholes and white holes, according to RadioAstron scientists. The trick is to keep our eyes peeled for a certain signature. "We must look for the structure of magnetic fields near the centres of galaxies," says Novikov, who back in 1964 also pointed out that general relativity allows for the

existence of white holes. "If the structures of the magnetic fields appear to be magnetic monopoles, that are macroscopic in size, then this is a wormhole. [These magnetic phenomena have only one pole and are predicted to exist but so far, like wormholes, have proven elusive]." It turns out that wormholes – specifically their white holes – will emit their own radiation, in contrast with black holes that don't emit radiation, but rather intensive radiation from the surrounding gas that spews out in swirls.

We might not have detected a wormhole for sure, but RadioAstron might be on to something. Turning its attention to the core of quasar 3C273, in the constellation Virgo around 2.5 billion light years away, it has found something unexpected. Quasars are active galactic nuclei producing enormous amounts of radiation from around their black holes. We know there's a black hole in the heart of 3C273, but RadioAstron's observations show that it has increased in temperature. There's also the magnetic field that Novikov mentioned earlier, so RadioAstron must verify the suspicions of theoretical physicists.

Meanwhile, instead of using telescopes to scan the skies for these tunnels, other astrophysicists have taken to imagining wormholes. For example, physicists Jensen and Karch have suggested that the particles of a quantum phenomena called entanglement are connected by miniature wormholes. When two particles interact they can become entangled so their characteristics correlate. The Heisenberg Uncertainty Principle means that the quantum states, or properties of the particles such as their spin, remain undefined until they're measured properly. However, when the spin of one of the entangled particles is measured, the other particle instantly follows suit, even if each of them are on opposite sides of the universe at the time.

How they communicate across huge distances so quickly is not truly understood, but Karch and Jenson have proposed that tiny black holes that have become entangled may have wormholes connecting them. Julian Sonner of the Massachusetts Institute of Technology has taken this idea a step further, showing that wormholes could connect entangled quarks, which are the fundamental particles that make up protons and neutrons inside of atoms.



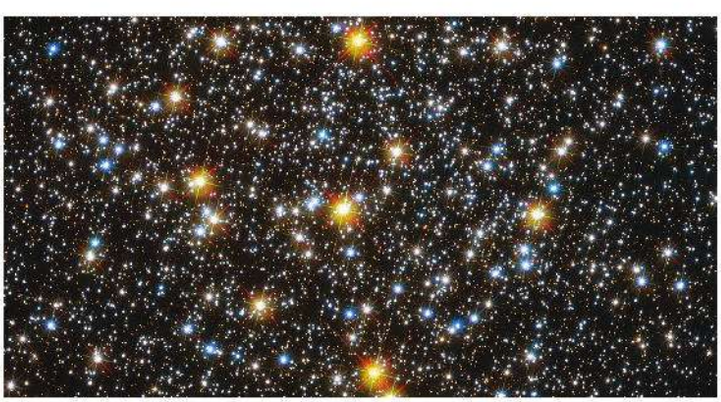
"It is natural to assume that in some cases mixed objects consisting of both ordinary matter and dark energy can exist"

Vladimir Folomeev

Another place where theorists are looking for wormholes is inside stars, although their location might make it difficult for us to reach them. Vladimir Folomeev of the Institute of Physicotechnical Problems and Material Science in the Kyrgyz Republic (Kyrgyzstan) has suggested that if exotic phantom matter exists then it's possible it could exist within stars.

"The idea is very simple," explains Folomeev. "If dark energy amounts to about 70 per cent of the total energy density of the universe, then it is natural to assume that in some cases mixed objects consisting of both ordinary matter and dark energy can exist." A mixed star would act oddly, affecting the star's mass and causing oscillations.

There are many places that wormholes could be hiding, from inside black holes and stars to the subatomic world, but what would it be like to travel down one? According to Davis, the mouth would look like a sphere with a distorted mirror image of the region of space on the other side of the wormhole, as the negative energy density deflects light passing through. When you pass through, the journey would likely be instantaneous and looking back you'd see another sphere reflecting where you came from. Across the universe in a single step – wormholes would be a truly giant leap.



An artist's impression of quantum entanglement. If two photons of light are allowed to properly interact with each another, they can become entangled

How many of the stars out there in the universe could harbour wormholes at their centres?

© NASA, Alamy

FOCUS ON

WEBB TELESCOPE TO GET BEST VIEW YET OF FAILED STARS AND ROGUE WORLDS

Not much is known about these tiny celestial bodies, which are hard to see

Reported by Stefanie Waldek

We're just weeks away from the release of the first images taken by NASA's James Webb Space Telescope, and while that occasion will be momentous, there is far more science to come. One of the James Webb Space Telescope's early programmes is a study that plans to use Webb to observe the nearby stellar nursery NGC 1333. The international team of scientists will image the stellar nursery's small, faint residents – primarily brown dwarfs and rogue planets – which have been difficult to see with less powerful telescopes.

Brown dwarfs are considered failed stars. Though they begin their lives in the same way as true stars – in clouds of collapsing gas and dust – they do not gather enough mass to begin fusion. Thus, they are quite small and do not produce bright light as other stars do, making them tough to see. Brown dwarfs exist somewhere between gas giant planets and red dwarfs, the smallest and coolest type of main sequence star.

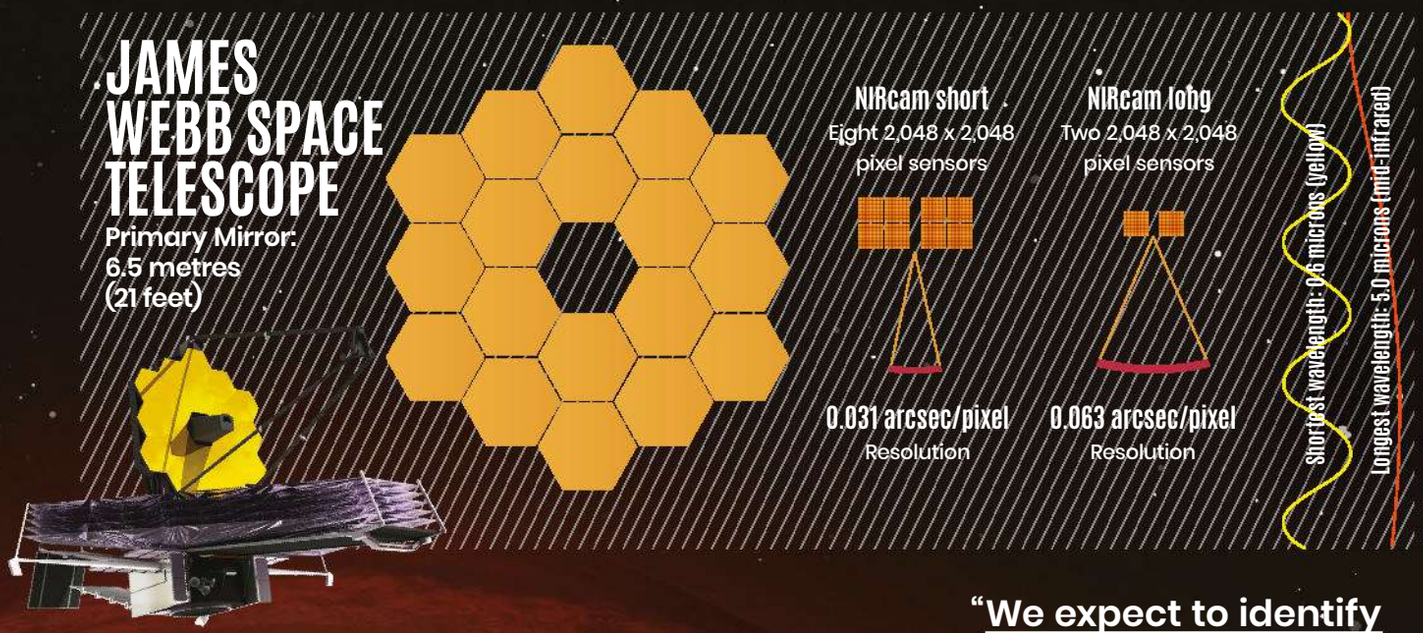
"The least-massive brown dwarfs identified so far are only five to 10 times heftier than the planet Jupiter," Alek Scholz, an astronomer at the University of St Andrews in Scotland and leader of the study, said. "We don't yet know whether even-lower-mass objects form in stellar nurseries. With Webb, we expect to identify cluster members as puny as Jupiter for the first time ever."

The team will also study rogue planets, or celestial bodies that formed in a stellar system before being ejected into space, left to float freely among the stars – true planets and exoplanets are gravitationally bound to stars. To observe these small, dark objects, the researchers will use Webb's Near Infrared Imager and Slitless Spectrograph, allowing the scientists to do spectroscopy on dozens of objects at the same time.

"For an unambiguous confirmation of a brown dwarf or rogue planet, we need to see the absorption signatures of molecules – water and methane, primarily – in the spectra," Ray Jayawardhana, an astronomer at Cornell University and a member of the research team, said. "Spectroscopy is time-consuming, and being able to observe many objects simultaneously helps enormously. The alternative is to take images first, measure colours, select candidates, and then go and take spectra, which will take much more time and relies on more assumptions."

The study is part of Cycle 1 of the Guaranteed Time Observations program, which will occur during Webb's first year of operations.

The telescope will observe NGC 1333, a nearby stellar nursery



"We expect to identify cluster members as puny as Jupiter for the first time ever"

Alek Scholz

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DID SCIENTISTS IN CHINA REALLY RECEIVE SIGNALS FROM ALIENS?

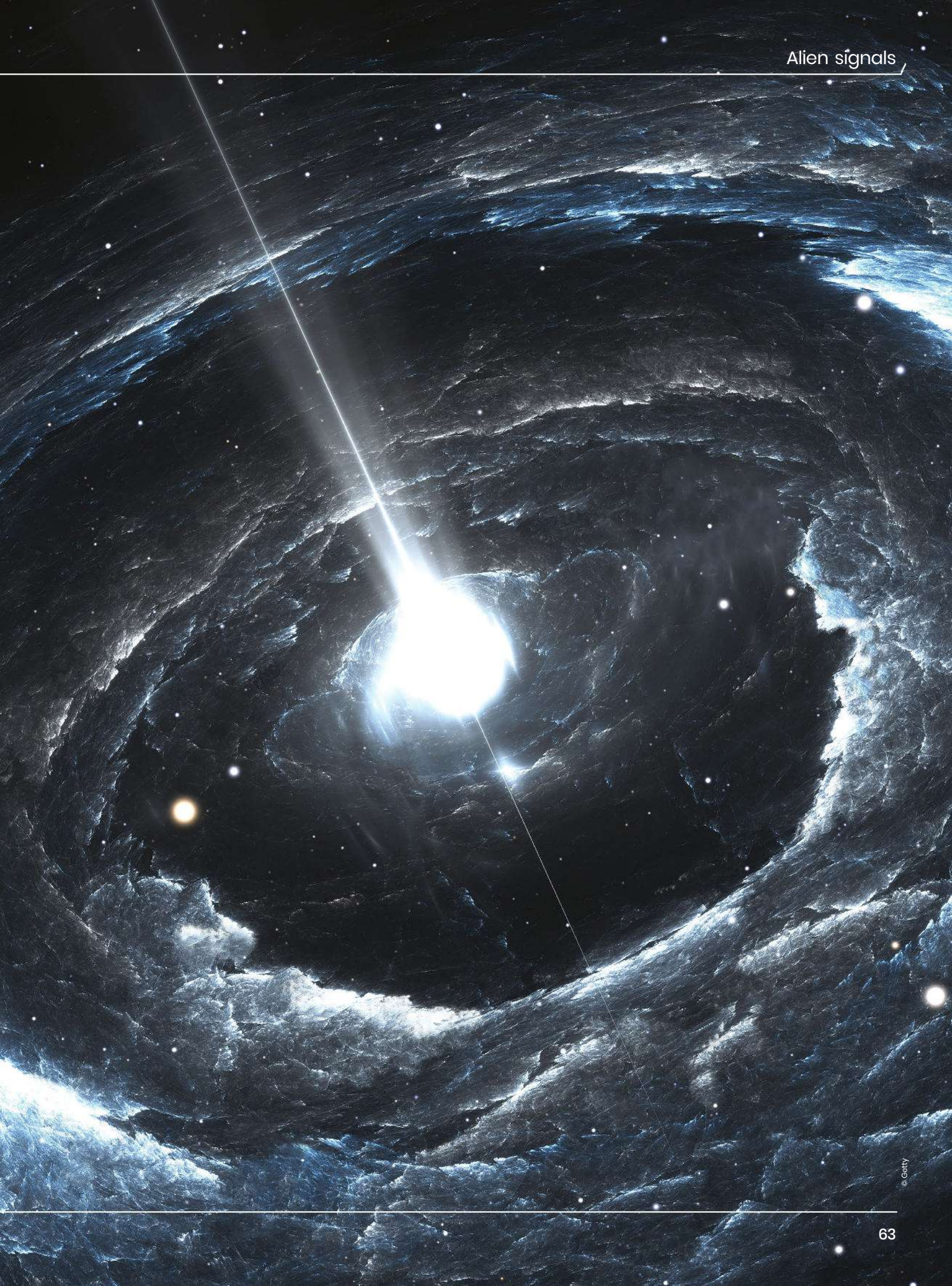
Chinese researchers reported three suspicious signals, potentially from an extraterrestrial civilisation... then the report was pulled

Reported by David Crookes

They say that in space, nobody can hear you scream. But if you listen very carefully, you may be able to pick up signs of distant chatter from extraterrestrial civilisations. That appeared to have happened recently when astronomers at Beijing Normal University issued a statement in *Science and Technology Daily*, the official newspaper of China's Ministry of Science and Technology, which reported the possibility of having detected trace signals from aliens.

Yet, just as researchers (and the general public) around the world were beginning to digest the news with interest, the statement was removed. A conspiratorial cover-up? Not quite. "The Chinese report of signals is – in my opinion – very likely to simply be radio frequency interference, from orbiting satellites most probably," says Dr Seth Shostak, senior astronomer at the SETI Institute in California. "I think the Chinese have said something similar themselves."

Indeed they have. But what the initial report showed was just how wide the ongoing efforts to communicate with intelligent alien life has become. Having begun in the 1960s, efforts were stepped up in the 1980s and are now arguably at their peak. With advanced technology, there is now hope of a breakthrough sooner rather than later – and Chinese scientists believe that they will do it first. On their side is amazing technology, notably the Five-hundred-meter Aperture Spherical radio Telescope (FAST) – the largest radio telescope in the world. Since it began officially operating in January 2020, it has been scanning deep space for radio signals that could help to prove the existence of intelligent life elsewhere in the universe.



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SIGNAL MONITORING BY NUMBERS

1977
The year the famous Wow! signal was detected. Scientists are still unsure of its origin

TWO
stars monitored for artificial radio signals by the first SETI search

17
Number of years taken to realise a microwave oven was causing strange signals

$100 MILLION
spent by Breakthrough Listen in the search for extraterrestrial intelligence

FIVE
The time in hours that a signal was detected in the direction of Proxima Centauri

2022
The year researchers devised a new message for potential aliens

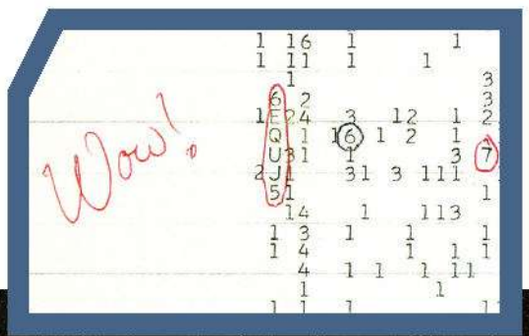
THREE
telescopes activity searching for life: FAST, Arecibo and James Webb Space Telescope

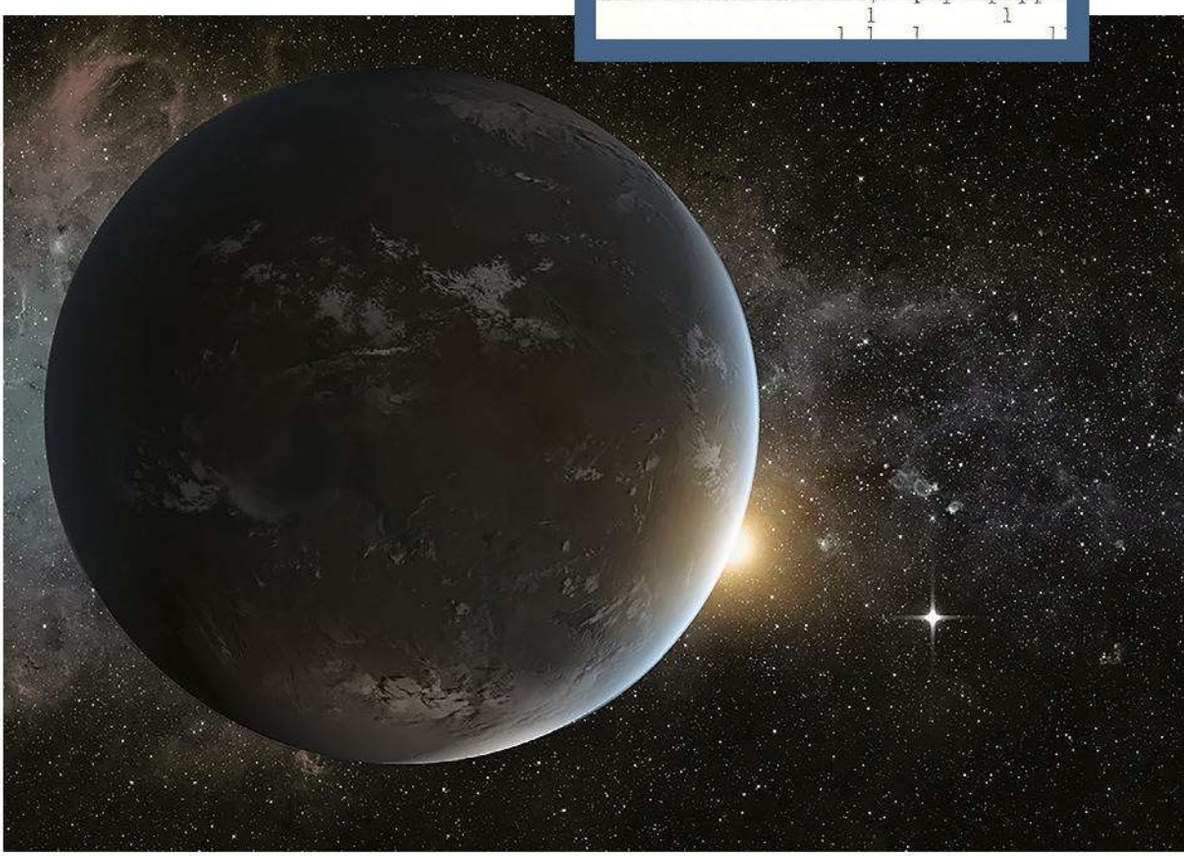
Dubbed China's Sky Eye and built between 2011 and 2016, it beat the US Arecibo Observatory's 305-metre telescope into second place, courtesy of a dish diameter of 500 metres (the Arecibo has since collapsed!). "FAST allows us to search for fainter or more distant signals," says Dan Werthimer, the Watson and Marilyn Alberts SETI Chair in the Astronomy Department and Space Sciences Lab at the University of California, Berkeley. "It might detect 'leakage' signals from another civilisation that wasn't meant for interstellar communication – perhaps something like a radar, television or navigation signal that wasn't meant for us."

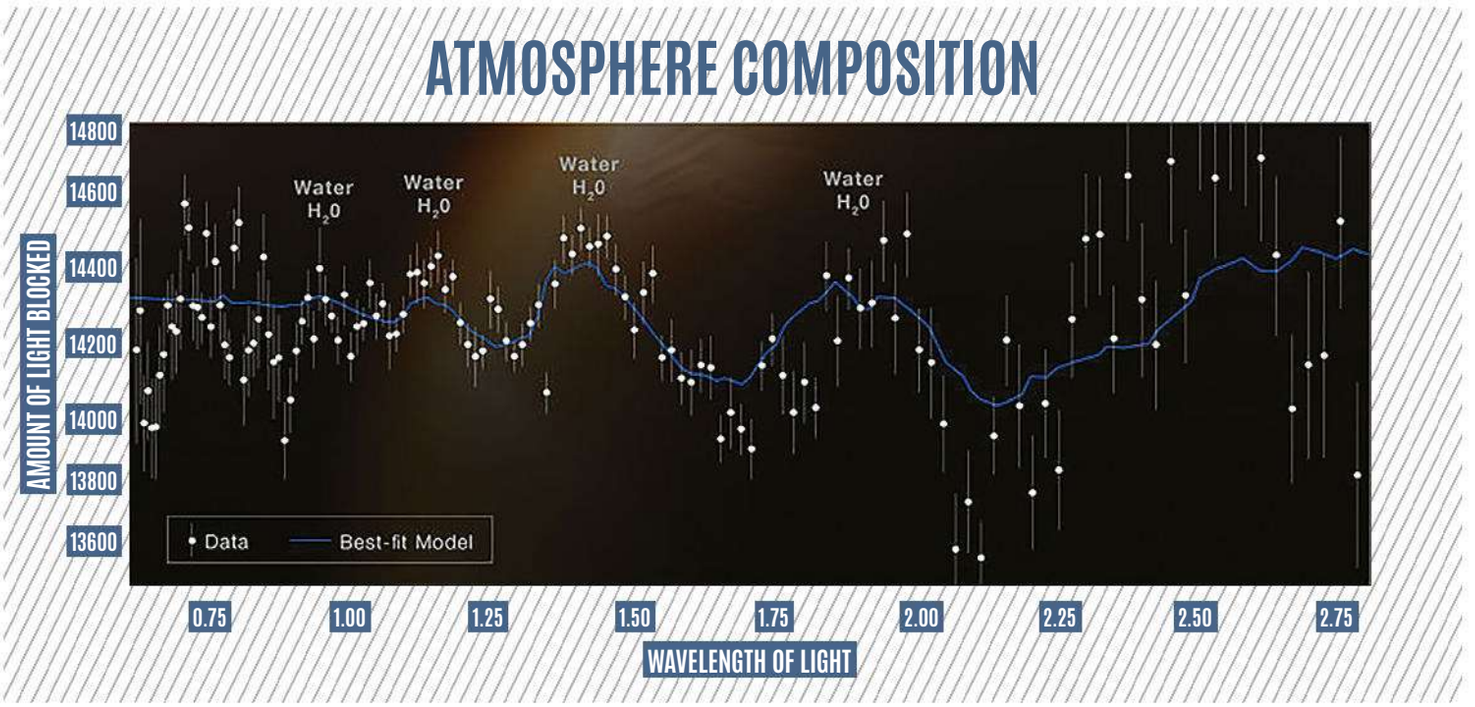
FAST is certainly one of the great hopes for the Search for Extraterrestrial Intelligence (or SETI, as it's better known). Costing 1.2 billion yuan, which is roughly $170 million dollars, and with a receiving area equivalent to 30 football pitches, it can pick up 37 gigabytes of information per second. But quite when a true breakthrough will come is anybody's guess. Werthimer is among those expecting it to be sooner rather than later. He works with the researchers at Beijing Normal University, the workplace of Professor Zhang Tongjie, chief scientist of the China Extraterrestrial Civilization Search Group of the Cosmology and Extraterrestrial Civilizations Research Group.

When Tongjie released his statement, he revealed the detection of three narrow-band electromagnetic signals "that are different from the past". Two of the radio waves were noted in 2020 and another was found this year. Each was of the type generally used by human aircraft and satellites. Since they appeared to be coming from distant space, it raised the possibility that the source was alien, leading to the statement being made. The fact that it was most likely radio interference came as no surprise – despite the telescope pointing upwards from a high vantage point in southwest China's Guiyang city, the capital of Guizhou province. Radio interference often ends up as the source of suspicious and mysterious signals and even the Chinese statement claiming potential alien contact raised it as a possibility.

"The signals so far are from radio interference – due to radio pollution from







earthlings, not from ET," Werthimer tells **All About Space**, with no hint of doubt. He goes on to explain that radio frequency interference can come from all manner of sources, from television transmitters, radar and satellites to cell phones, electronics and computers located near the observatory. But he says it's to be expected. "It's not surprising that all of the signals so far have turned out to be interference," Werthimer says. "Earthlings are just getting in the game, just scratching the surface, and very little of the spectrum and very few signal types have been explored." This will change in the coming years and decades, with interest in SETI appearing to strengthen.

Werthimer has proof of the strong interest in discovering intelligent life away from Earth. As co-founder and chief scientist of the SETI@home scientific experiment, which began in 1999, Werthimer saw a willingness by the public to aid the search for extraterrestrial intelligence. The public volunteer computing project ran until 2020, the year it was paused. Over those 20 years, people allowed their idle computers to process radio signals from outer space for signs of alien transmissions. It enabled lots of data from the Arecibo radio telescope and the Green Bank Telescope to be crunched.

"The vast majority of the public is interested in SETI," Werthimer affirms. "8 million people in 226 countries helped us to make the most sensitive SETI search ever done, using their home computers." And yet, as he says, a different approach may well be needed in the future.

> "Earthlings are just getting in the game, just scratching the surface, and very few signal types have been explored"
>
> **Dan Werthimer**

The Wow! signal was detected in 1977 and lasted for 72 seconds. In the range of frequencies similar to artificial signals, it's never been conclusively explained

The 'alien signal' at the centre of recent attention had come from the direction of exoplanet Kepler 438b – an Earth-like planet

WHAT DID THE CHINESE ASTRONOMERS DETECT?

It was announced as a suspicious signal (then withdrawn) but what lay behind it?

An alien race

When news emerged that scientists in China had discovered three signals at a frequency of 140.604 MHz, an official report suggested they could be from a distant alien civilisation. The report was quickly deleted, but some have suggested the Chinese government wants to keep it quiet. That's unlikely.

Radio frequency interference

The scientists identified the signal – from the direction of the rocket planet Kepler 438 b – as radio frequency interference (although the planet is in a habitable zone). The discoverers said the possibility of it being radio interference was "very high". This remains the most likely explanation.

A natural phenomenon

Could the signal have come naturally from somewhere, like a star? No. The fact that it was of a type that does not occur naturally rules this out. Again, it doesn't point to aliens because the signal's source, while artificial, was one that could have been produced by human-made technology.

© NASA; Getty;

"It's getting hard to do SETI observations from the surface of our planet," Werthimer says. "Radio pollution is getting worse as more and more transmitters are built and some radio bands have been impossible to use.

"Earthlings might eventually have to go to the backside of the Moon to search for extraterrestrial intelligence because a radio telescope in that location would be shielded from all our planet's radio pollution."

For now, telescopes such as FAST are useful and scientists are getting sufficient time for their SETI research. "We are working on a three-year sky survey which uses about a third of the time on FAST," says Werthimer. "The survey searches for pulsars, fast radio bursts, ET as well as mapping hydrogen gas in our galaxy and distant galaxies. We also have a couple of days a year for targeted searches of nearby stars."

Tongjie is also confident that FAST will be the first to discover and confirm the existence of extraterrestrial intelligence. Having spent years persuading China to join the search, he's not about to waste the opportunity, grasping access to China's humongous telescope with great enthusiasm while no doubt understanding the Chinese authorities will be expecting results at some point. If discoveries are made, then future time with the telescope will be assured, but it remains a big 'if'. It's one thing to firmly believe there is intelligent life somewhere away from Earth, and quite another to actually find it.

Funding in this field is already hard to come by, and there's a lot of scepticism, usually tied in with the perception that scientists are looking for 'little green men'. The next time a breakthrough announcement is made, scientists may need to be more sure. As it stands, they're trying to target the most likely parts of the sky, with 70 Milky Way solar systems having been identified for FAST.

"Although the recent signals have been from terrestrials, not extraterrestrials, I'm optimistic about life and intelligent civilisations in the universe," says Werthimer. "There are a trillion planets in our galaxy and a trillion galaxies. Life also got started on Earth very quickly, as soon as it cooled down, and simple life might even be in our backyard, in Enceladus or Europa, which have liquid water oceans."

THE WORLD'S LARGEST SINGLE-DISH RADIO

How the Five-hundred-meter Aperture Spherical radio Telescope (FAST) can search for extraterrestrial civilisations

1 Lending support
FAST is located in a naturally deep and round mountain basin in China's Guizhou Province at an altitude of 1,000 metres. The six towers support the receiver.

2 Receiving signals
The mammoth 500-metre wide reflector is made up of 4,400 adjustable triangular panels, sending data to the receiver. It can detect signals from up to 13.7 billion light years away.

3 Sensitive soul
FAST has a high sensitivity in the low-frequency radio band. It's capable of detecting radiation at radio wavelengths of up to 10 centimetres and can process 38 billion samples of data every second.

4 Sky Eye
Dubbed Sky Eye, FAST's search for technosignatures that can point to extraterrestrial intelligence can be conducted alongside the telescope's primary science programs.

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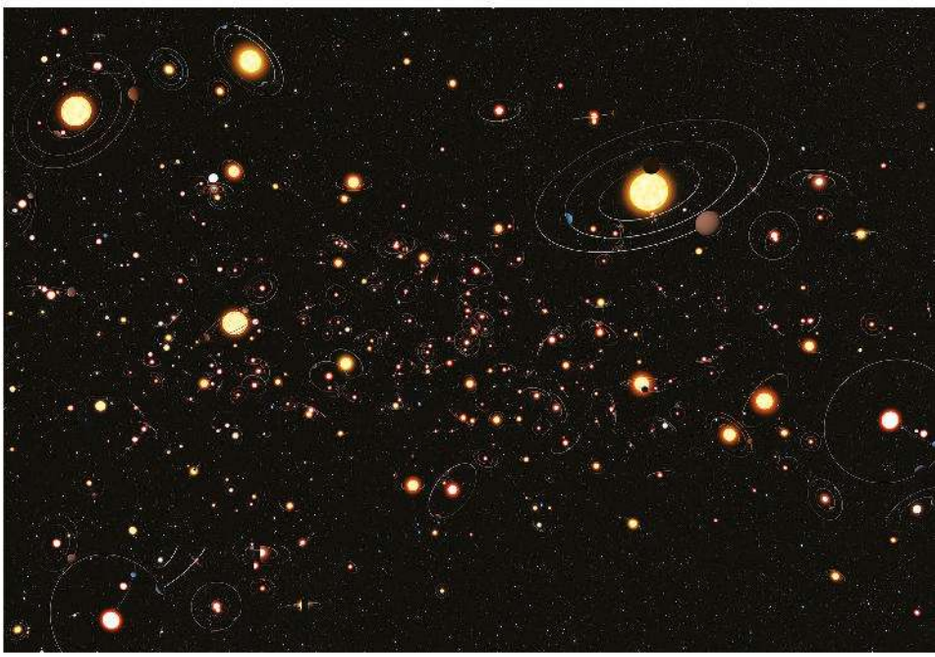

The Milky Way contains more than 100 billion planets and FAST is being used to focus on 70 of the galaxy's solar systems

As well as radio frequency interference, there are numerous other obstacles to overcome, not least the presumption that alien civilisations are transmitting signals in the first place! "Yes, SETI is a search for technosignatures – artefacts from technology," Werthimer explains. "Current SETI searches don't have the capabilities to detect fires or pyramids from civilisations similar to Ancient Egypt or cave people." It means extraterrestrials will need to be more advanced than that.

"Current technosignature searches can detect waste heat from a civilisation such as Dyson spheres [a theoretical mega-engineering project that encircles a star with platforms orbiting in tight formation], or radio, radar, TV, or narrowband or pulsed signals at visible or IR wavelengths, so ET would have to be at least at our technological level," Werthimer explains. "But our solar system is middle-aged – about 5 billion years old. Many stars and planets are billions of years older, so there could be very advanced civilisations out there."

When asked how likely this would be, he points to the work of astrophysicist Ray Norris, which offers some encouragement in the ongoing search. "Ray Norris calculates that the first civilisation that earthlings' contact will likely be a billion years ahead of us and those civilisations are likely easier to detect," Werthimer says. "The chance of finding an emerging, new civilisation like our's, which has just recently discovered radio and lasers, is very small. It's a blink of an eye (100 years) in the history of life on Earth (4 billion years)."

Yet, searching for technosignatures is only one way of looking for alien civilisations. Biosignature searches, for example, look for molecules in the atmosphere that indicate life ("oxygen might indicate photosynthesis," Werthimer says) and these too have given increased hope for those involved in SETI.

"The James Webb Space Telescope team has just released an amazing detection of water in the atmosphere of exoplanet WASP-96b," says Danny Price, a senior postdoctoral fellow at the International Centre for Radio Astronomy Research in Perth. "Using the same approach, JWST may be able to find biosignatures in the atmosphere of other exoplanets which would indicate the presence of biological life. That's incredibly exciting."

Like Werthimer, Price believes FAST has the potential to be a breakthrough tool. "It's an amazingly sensitive telescope, which means it can detect fainter signals coming from further afield," he says. Yet he suggests we should be cautious. "FAST is not very good at localising where on the sky a signal came from," he adds. "New multi-element telescopes such as MeerKAT and the upcoming Square Kilometre Array (SKA) will be exciting for SETI, as their localisation capabilities are far better."

One thing's for sure: announcements that potential aliens are somewhere out there – even those that end up being pulled – will continue to turn heads and generate headlines. In the same way as Dmitry Rogozin, the director-general of Russia's space agency Roscosmos, attracted attention when he said Russian scientists were going to be investigating UFO sightings, there's a natural curiosity regarding alien life. NASA is stepping up efforts to investigate unidentified flying objects (or unidentified aerial phenomena, as it prefers to call them), although this is also to help identify advanced technology from a foreign power.

If nothing else, such studies let us probe the unknown. "It's a question humans have been asking for a few hundred thousand years: are we alone? The answer is profound either way," says Werthimer. "We could find the universe is teeming with life and get on the galactic internet, learning about how other civilisations billions of years ahead of us survived their early days when they were still killing each other and learning about their cultures, music and art.

"But if earthlings learn we are alone, that would make life incredibly precious. We would need to take care of our planet and each other."

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

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China's Five-hundred-meter Aperture Spherical radio Telescope (FAST) has found several possible technical traces and suspected signals of extraterrestrial civilizations, said the research team from Beijing Normal University, which is further exploring the information.
7:43 AM · Jun 14, 2022
834
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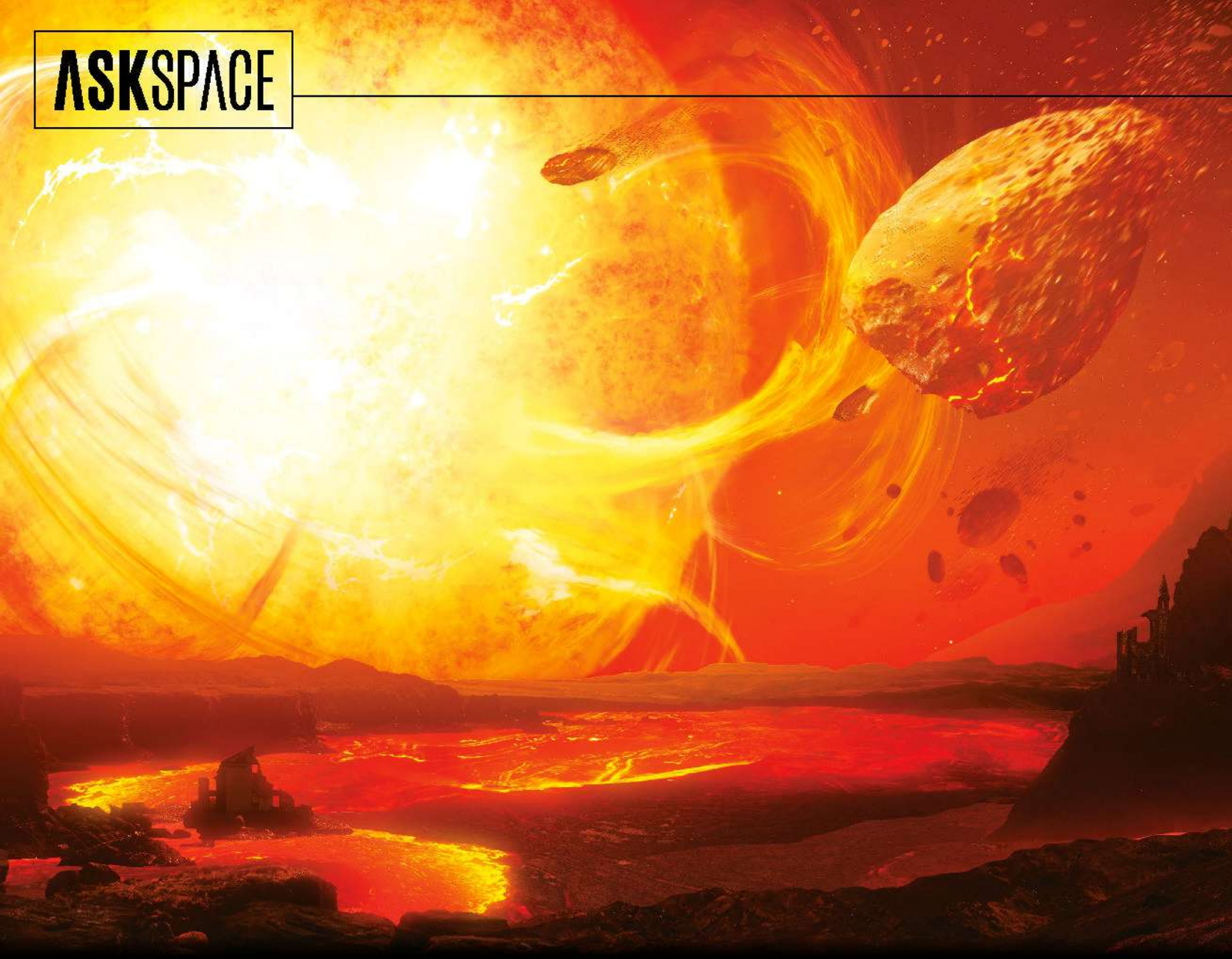
China's state-affiliated media picked up on the report, as this tweet from *Global Times* shows



SOLAR SYSTEM

How will Earth end?

I would say the most likely fate for Earth as we know it will come from within. Whether it is a nuclear war, mutated virus, climate catastrophe or collapse of civilisation, you only need to look at history to see where the future may go. That's part of my reason for believing humanity should establish a second biosphere to safeguard civilisation, culture and technology from our mistakes, sort of like seed banks.

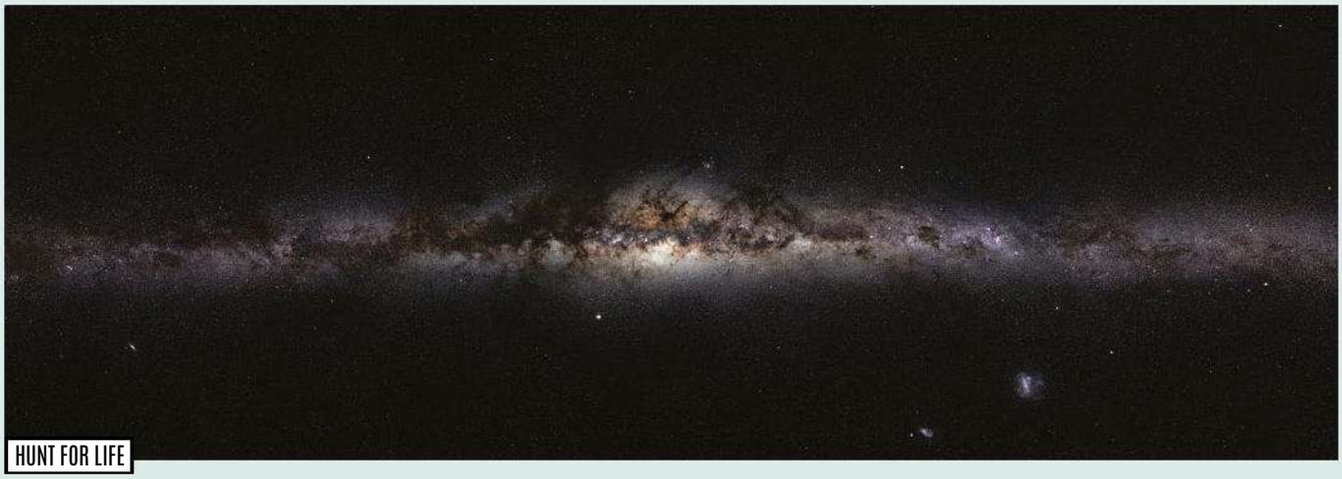
Those human-made collapses would still yield the most life-friendly planet in the Solar System. We have a long time until the Sun turns into a red giant and our oceans boil away. Hopefully we will be out of the Solar System by then. There is always the Jovian system, which might be more habitable as the Sun gets bigger.

Long before the Sun starts to die, Earth will be impacted by a large asteroid or comet, perhaps at the same scale of the impact event 65 million years ago. But life even survived then, and Earth returned to a habitable state. Again, if we had a second biosphere, human civilisation could return to Earth once it was habitable.

Dr Patrick Troutman, lead for human exploration strategic assessments at NASA's Langley Research Center

"Humanity should establish a second biosphere to safeguard civilisation, culture and technology from our mistakes"

Earth has bounced back after disasters in the past



HUNT FOR LIFE

How would we recognise other life in the universe?

Even if primitive life and vegetation were ubiquitous, 'advanced' life may not be. Our emergence on Earth may have depended on many contingencies, such as the phases of glaciation, the planet's tectonic history, the presence of the Moon and so forth. But searches are surely worthwhile. Instruments are searching for non-natural radio transmissions from nearby and distant stars, from the plane of the Milky Way, from the galactic centre and from nearby galaxies. But even if the search succeeded, it would still be unlikely that the 'signal' would be a decodable message.

A radio engineer familiar only with amplitude modulation might have a hard time decoding modern wireless communications. Indeed, compression techniques aim to make the signal as close to noise as possible – insofar as a signal is predictable, there's scope for more compression. And the signal could just be 'leakage' anyway, rather than any kind of message.

Then again, many of us think that 'organic' human-level intelligence is just a brief interlude before the machines take over – before 'organics' are overtaken or transcended by inorganic intelligence, which will then persist, continuing to evolve for billions of years. This suggests that if we were to detect extraterrestrials, it would be far more likely to be inorganic: we would be most unlikely to 'catch' alien intelligence in the brief sliver of time when it was still in organic form.

Martin Rees, British cosmologist, astrophysicist and Astronomer Royal since 1995

A Could life actually be widespread across the Milky Way and beyond?

V Kelly has spent a total of 520 days in space, including a year on the ISS

SPACE EXPLORATION

What's it like spending a year in space?

With the usual six-month stay you can kind of see the end and you think, "I launched in October and I'm coming back in March; I can envision getting there." But when you launch in March and you're thinking about coming back the next March, it's not something you can really comprehend. I think the perfect duration is somewhere on the order of two-and-a-half to three months. When you get to [that stage] you think, "I've really been here for a long time." To know that you have nine months to go is kind of hard to get your head around. As far as coming back, I was kind of surprised how I felt different physically than the last time with regards to muscle soreness and joint pain, and then there is the skin issue.

Scott Kelly, former NASA astronaut

© NASA; ESO; Tobias Roetsch

ASTRONOMY

Why do we use radio to observe the universe?

There's particular science that can only be done in radio wavelengths. You just need to look back at the last 30 or 40 years or so of astronomy – a lot of the big discoveries have been made at radio wavelengths. Particularly the pulsars, which were discovered in the UK, could not have been done in any other wavebands. I'd say that this is a very big example of needing to study the universe in radio wavebands.

Things like looking at complex molecules – which are very interesting for people looking for life in the universe – is another example and one which is going very well in radio wavelengths. And looking back in time is also very good in long radio wavelengths, since they can see through all of the obscuring matter in space in order to go way back to the beginning of the universe, which can be very hard to do at optical and other wavelengths. It's the way that a lot of astronomy has been done.

Tyler Bourke, senior scientist for the Square Kilometre Array

© NASA/ESA; Source: Wikipedia commons; Mike Peel;

ASTROPHYSICS

How can stars create crystals?

Regular stars like the Sun remain gaseous because they have a nuclear source of energy. But when the Sun dies it will become a large red giant star for a short time, and then a compact white dwarf. Without any source of energy, white dwarfs cool over timescales of billions of years. After a few billion years of cooling the liquid interior abruptly transitions into a solid, which slows down the evolution. It's much like if you were doing the experiment on freezer water. If you used a thermometer, you would realise that it remains at the same temperature for a while before it cools down more rapidly. The same happens in white dwarfs where the freezer is the dark and empty universe, but the transition happens at 10 million degrees because of the densities involved. The atoms are ordered in a cubic lattice because it minimises the potential energy. The thin surface layers of the white dwarf will remain gaseous for another 10 to 20 billion years until they reach room temperature. After that, the white dwarf is a fully solid crystal and stable for at least 10^{20} times the current age of the universe.

Pier-Emmanuel Tremblay, associate professor at the University of Warwick

A The pressures in a white dwarf star can result in interior crystals

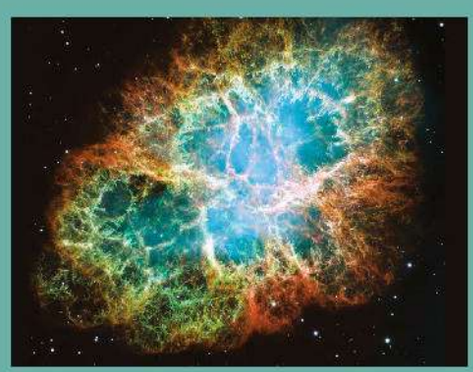
V The Crab Nebula is an ancient supernova remnant

ASTROPHYSICS

How close would a supernova have to be to destroy life on Earth?

If a supernova was to go off within about 30 light years of us, that would lead to major effects on Earth – possibly mass extinctions. X-rays and more energetic gamma rays from the supernova could destroy the ozone layer that protects us from solar ultraviolet rays. It could also ionise nitrogen and oxygen in the atmosphere, leading to the formation of large amounts of smog-like nitrous oxide.

Supernovae happen about once every 100 years in the Milky Way. But the Milky Way is a big place, roughly 100,000 light years across. Given that – and the fact that the Sun is near the outskirts of the Milky Way where few stars massive enough to become supernovae are born – having a supernova within 30 light years of the Sun should, on average, happen only once in every 100 million years.



Dr Mark J. Reid, senior radio astronomer at the Harvard-Smithsonian Center for Astrophysics

ASTROPHYSICS

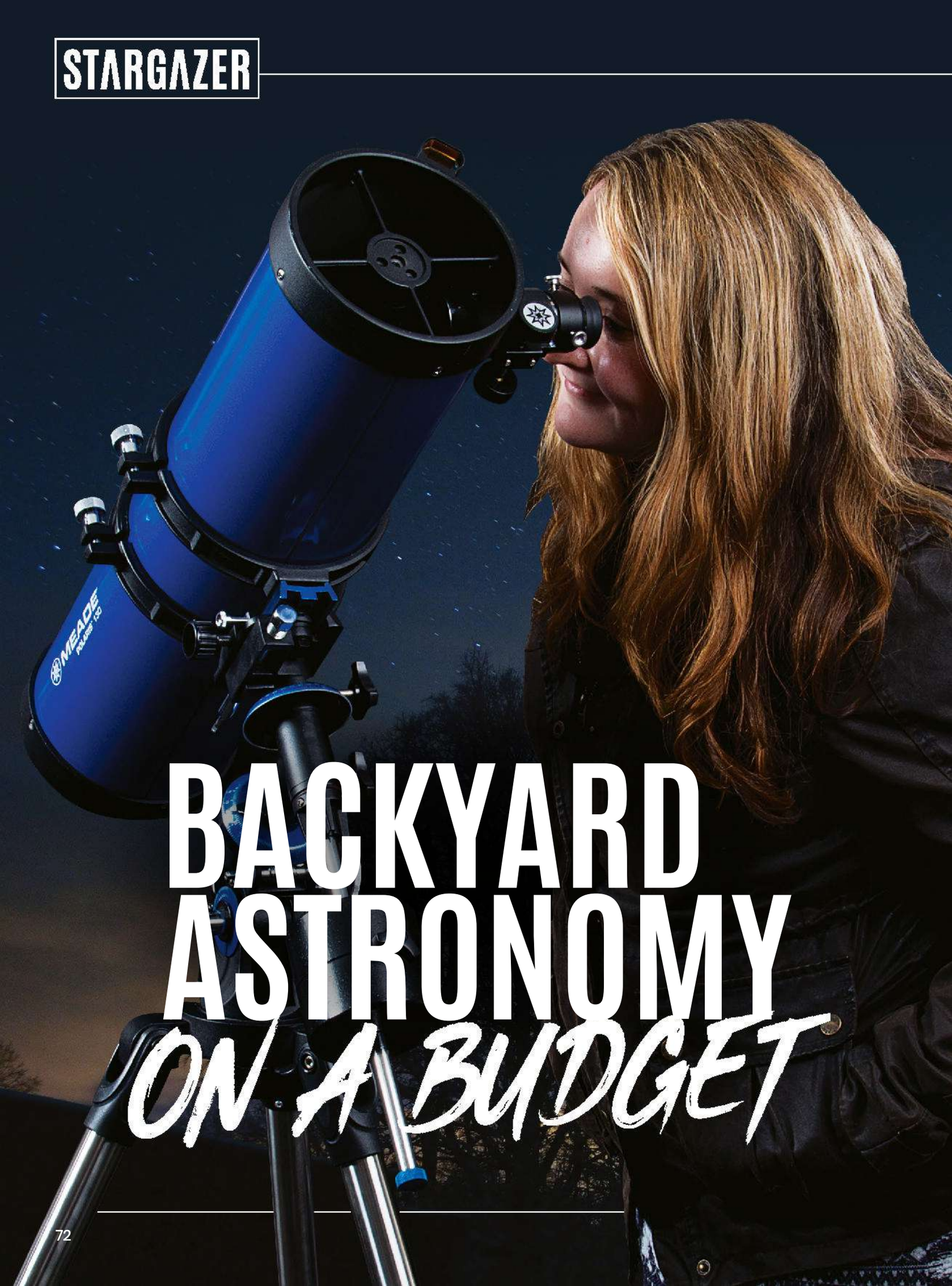
How much alcohol is in space?

There's a great deal of alcohol in space, and I mean that not just by volume, but also by variety. There are vast oceans upon oceans worth of ethanol, or ethyl alcohol – the kind we might drink in beer or wine or cocktails – floating in great interstellar clouds, the birthplaces of stars and planets. But there is also a wide variety of other molecules that we chemists classify as alcohols. The most abundant and widespread of these is methanol, or methyl alcohol, and is actually chemically simpler than 'drinking alcohol'.

On Earth it's most commonly known as a toxic byproduct of home-distilling operations. In space it is one of the most common organic molecules and is the feedstock for a multitude of reactions that lead to far more complex chemistry occurring in the universe. Some of these more complicated alcohols, like methoxymethanol, have been found by researchers in recent years.

Brett McGuire, Hubble fellow at the National Radio Astronomy Observatory and the Harvard-Smithsonian Center for Astrophysics

With the amount of alcohol in space, astronauts could have a great time



BACKYARD ASTRONOMY *ON A BUDGET*

All About Space brings you all of the fun of astronomy without breaking the bank

Written by Jamie Carter

When it comes to choosing and purchasing equipment to observe the night sky, there's a lot to take in. Which telescope should you get? Which magnification is best for your first binocular? Do you need to buy extra eyepieces? These are just some of the questions that you may have found yourself puzzling over when choosing astronomy kit. It may be that the daunting task of selecting telescopes or binoculars has put you off pursuing a hobby in astronomy. Maybe you have bought a telescope that doesn't meet your requirements and is too complicated for you to use. If you took the plunge before you were ready, it's most likely left you feeling frustrated and disappointed, with nothing to show for your efforts other than a piece of equipment gathering some dust in a rarely visited corner of your home – not to mention a lower bank balance.

Blunders like this aside, it certainly is possible to take part in backyard astronomy without having to spend an incredible amount. The trick is to do your research, whether that involves reading up on your hobby in stargazing books or getting some advice from a seasoned amateur astronomer at your local astronomical society before you make your first purchase. It's also essential that you shop around to compare prices, making sure that there's a trade-off between how much you can afford and what a piece of equipment can actually offer.

Lastly, you should always think ahead – will your equipment still be usable a year into your backyard astronomy hobby? Where first-time astronomers often get lost is not being able to figure out what they should be looking for in an ideal piece of equipment, with newcomers often thinking that bigger and more expensive is better. This isn't always the case. It's always down to the individual and your specific needs, and a telescope that enables you to do what you want at a reasonable cost is definitely a step in the right direction when it comes to figuring out a budget.

Still at a loss? Don't worry. This guide will ensure you get what you want for many worthwhile evenings under the stars, with minimal fuss and without breaking the bank.

"It certainly is possible to take part in backyard astronomy without having to spend an incredible amount"

FIND YOUR WAY AROUND THE NIGHT SKY

Getting a good idea of the constellations and identifying naked-eye objects such as planets, star clusters and prominent stars will help you find objects with the equipment you're intending to buy later on. These objects can act as signposts in the night sky, pinpointing hidden treasures for future observations. If you're unfamiliar with what's out there and unsure of the prime targets during the spring, summer, autumn and winter skies, then you should certainly invest in a planisphere or a guide to the night sky. This won't just show you where everything is, but which objects you can observe throughout the calendar year. Your planisphere will be a guide that you can use over and over again. Remember, there's no time limit to how long you should spend partaking in naked-eye astronomy, so take your time in getting acquainted with the heavens.

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YOUR FIRST BINOCULAR

Binoculars are the way to go when it comes to using your first piece of equipment. Not only do they promote minimum fuss and can be turned to any object with ease – unlike a telescope which may need polar alignment – but the binocular that you're likely to be using doesn't require any setting up. You'll also have much more freedom of movement, magnifying objects without spending a great deal of money. If your budget is less than £100 ($120), it may be worth investing in a good binocular rather than a low-quality telescope. Remember that your binocular can also be used as a sight-seeing aid as well as for nature-watching, providing a multitude of uses in one hit.

You'll find that binoculars are usually marked with figures such as 8x40, 7x50 or 10x50 – the first figure is the magnification, while the second is the aperture of the lenses built into the binocular in millimetres. For casual observing your best bet is to go for 7x50 or 10x50 binoculars, since they are both equally useful. Remember that the greater the aperture, the heavier the binocular usually is, so if you find that 50mm is too heavy for you to hold steadily, opt for 40mm or even 30mm models. Alternatively, when it comes to the compromise between weight and power, many go for 8x32 or 8x42 binoculars.

The heavier the devices get, the more likely you'll need a tripod – it'll be difficult to observe anything when your arms are shaking under weight, so choose wisely.

Binoculars are a good step towards a telescope

"It may be worth investing in a good binocular rather than a low-quality telescope"

Go for...

✓ Binoculars with coloured coatings on their optics – these will improve image brightness

✓ Binoculars with a good balance between light-gathering capacity, magnification, weight and cost

✓ Porro or BAK-4 prisms that offer 8x magnification and reasonably large objective lenses of 42mm plus

Avoid...

✗ Magnifications greater than 12x, unless you have a particular need for specialist binoculars

✗ Binoculars that are too heavy for you to hold – they'll be difficult to keep steady without a tripod

✗ Zoom binoculars – they have narrow fields of view and relatively poor optics

YOUR FIRST TELESCOPE

At this stage, you might be looking to upgrade your binoculars to look deeper into the night sky. Before you purchase a telescope, however, there are a few things you should consider. First, think about whether you're familiar enough with the night sky, and secondly ensure that buying a telescope will improve your observing experience. There's little point in spending more money on a telescope when it doesn't give much more magnification than binoculars or if it's likely to end up gathering dust in your home. Before buying anything, it's always best to consider these factors.

Choosing your telescope can be a challenge when you don't know what you're looking for, so once again it's important to know how much you're willing to spend and what capabilities you want your telescope to have. It's said that refractors are best for checking out the craters on the Moon and the planets, while a reflector – capable of collecting more light – is best for fainter, more diffuse nebulae and galaxies.

At this stage it's best not to limit yourself, so go for an all-round telescope that can show you a wide range of night-sky gems. These are often referred to as Newtonian or hybrid Schmidt-Cassegrain, Maksutov-Cassegrain or catadioptric telescopes. It may be tempting to opt for a GoTo telescope, which can point you to any object you wish. However, these can be difficult and time-consuming to set up.

Many beginners are attracted to what a Dobsonian – a type of Newtonian telescope – has to offer in the trade-off between price and overall performance. A good sturdy Newtonian should cost you around £200 ($240), while a good refractor could be as little as £300 ($360) with a tripod and eyepieces to start you off. If you ensure you buy from a well-respected telescope dealer, or perhaps even someone experienced at your local astronomical society, you can't go too wrong.

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Go for...

✓ Telescopes that come as a complete package – most come with a tripod, finderscope and an eyepiece or two

✓ An instrument that meets your needs – don't buy an expensive telescope blindly without doing any research

✓ The higher the aperture, the better. The larger it is, the sharper and brighter your image

✓ Good focal length, depending on the objects you want to view. Get long focal lengths for high-power objects like the Moon and planets and shorter focal lengths for taking in larger areas of sky

✓ A steady, sturdy and smoothly working mount

Avoid...

✗ Cheap, poor-quality models that you can often find being sold in high-street stores or in mail-order catalogues

✗ Telescopes that are particularly difficult to set up

✗ Devices that offer fantastic magnification for very little cost – if it sounds too good to be true, then it most probably is

✗ Telescopes that are too heavy for you to carry

✗ Devices that come with eyepieces with barrels less than 1.25"

✗ A finderscope with a tube hardly thicker than your finger or that gives a dim, fuzzy view

FILTERS AND EYEPIECES: GET THE MOST FROM YOUR TELESCOPE

Eyepieces work with your telescope's focal length and aperture to increase the magnification. Filters will give you a more enhanced observing experience when it comes to looking at planetary features such as the dust storms on Mars, the Moon and the faint dust and gas of diffuse nebulae. You're very likely to be supplied with some higher and lower power eyepieces with your telescope, but you may not be getting the most out of your device with these alone. It's worth considering if you can improve your instrument with a small amount of money before deciding to upgrade your telescope in the future.

The best types of eyepieces to go for, giving great viewing for little cost, are Plössls. Remember that the larger the value on the eyepiece, the lower the magnification you'll get. It's also important to have a sense of how much magnification your telescope can handle, but eyepieces can be extremely useful in giving your telescope a much needed power boost. Alternatively, you might decide to invest in a Barlow lens, which you can fit to your telescope to boost the magnification of the eyepieces that you already have, saving money in the long run.

Go for...

✓ Some alternative achromatic eyepieces for your device

✓ Ensure that your eyepieces come multi-coated

✓ Consider acquiring a Barlow lens to boost the power of eyepieces you already have

✓ The highest quality filters that your budget will allow

Avoid...

✗ Wasting money on eyepieces that your telescope is going to struggle to handle

✗ Eyepieces with eye relief values that are too low for you

✗ Eyepieces that are too heavy for a delicately balanced telescope – even with a sturdy tripod

SOMETHING FOR THE KIDS

Perhaps your children, grandchildren, nieces or nephews have been pestering you for a telescope. You're not sure of which telescope to purchase, or maybe you're worried about purchasing a top-of-the-range telescope that they could get bored of within a few weeks. Luckily there are telescopes that are relatively robust, require no setting up and cost below £100 ($120) that tick all of the boxes for an entry-level telescope for youngsters. These sturdy scopes will allow them to see the Moon closely, as well as some of the planets. What's more, they can just sit on the windowsill, doubling up as an ornament that can easily be packed away and stored. These desktop starter telescopes usually feature a dobsonian mount – brilliant for the beginner – and come with a selection of eyepieces and a filter or two.

"There are telescopes that are relatively robust, require no setting up and cost below £100 ($120)"

TELESCOPES UNDER £500 ($600)

Celestron FirstScope
From: Amazon
Cost: £67.88 / $71.95
Grab an ideal budget telescope for any budding astronomer out there. It's a tabletop model with a 76mm reflector optical tube and is very lightweight and portable. Its stylish finish means it's a great little telescope for any young person who wants to grow their passion for astronomy.

Celestron PowerSeeker 60AZ
From: Amazon
Cost: £78.99 / $79.95
You can pick up this model for a bargain. This is definitely a starter scope, aimed at kids and beginners, with a straightforward alt-azimuth mount and a relatively small 60mm aperture. Still, it offers some good lunar views and it's relatively well-powered for its very low price.

Celestron StarSense Explorer DX 102AZ
From: Amazon
Cost: £379.99 / $455.58
This works with the StarSense app, which means stargazing is made that much simpler. The app can point out and name the objects you're looking at, and the telescope itself is light, meaning it's easier to transport wherever you want to use it.

Orion StarMax 90
From: Amazon
Cost: £221.29 / $319.99
This is a tabletop telescope, so it can rest easy on your desk and you can use it at your own leisure. There's no setting up a tripod and it's quick and easy to use as well as set up. The telescope comes ready to use out of the box and offers a decent-sized aperture and good-quality optics for the price.

Celestron AstroMaster 102AZ
From: Amazon
Cost: £296.86 / $299.49
This refractor has a decent-sized aperture and a lightweight, portable design. It's easy to operate, with a panning handle that allows you to sweep the night sky and slow-motion controls for fine movements. It's light, so easy to manoeuvre around a backyard or dark camping spot.

Orion SpaceProbe II 76mm reflector
From: Amazon
Cost: £110.49 / $129.99
A reflector that offers wide-field views but performs well with lunar and planetary observations, this is a good option for young stargazers. It comes with everything a budding astronomer needs, including 10mm and 25mm Kellner eyepieces, a red-dot finder and Moon map.

StarSense Explorer DX 130AZ
From: Amazon
Cost: £378.50 / $449
The wide 130mm aperture on this Newtonian reflector unit makes it a great option for viewing lots of the night sky, including galaxies, nebulae, planets and star clusters. It's one of our favourite telescopes for beginners, as it works in conjunction with the StarSense app on your mobile phone.

Orion StarBlast II 4.5 EQ
From: Amazon
Cost: £250 / $240
This telescope has a solid build. It comes with an impressively long list of accessories including two eyepieces, a 2x Barlow lens, Orion's Star Target Planisphere and Telescope Observer's Guide for planning your observations, a moon map, a red LED light to preserve your night vision and a red-dot finder.

Sky-Watcher Heritage-130P FlexTube
From: Wex Photo
Cost: £195 / $210
This is a tabletop model and great for astronomers to use at their own leisure. Because of its tabletop design and size, it's great for carrying around wherever you're on the move to and it's easy to use and set up too, so you don't need an in-depth knowledge of how telescopes work to be able to use this model.

Celestron Inspire 100AZ
From: Jessops
Cost: £229 / $300
This refractor telescope comes with plenty of accessories, including a smartphone adapter that will allow you to take images of the night sky. However, given that the refractor boasts a focal ratio of f6.5, you're limited to short-exposure photography here. But it is a nice piece, all the same.

Celestron PowerSeeker 127EQ
From: Amazon
Cost: £199 / $170
An excellent entry-level telescope, this reflector model boasts a powerful 127mm aperture and comes with an equatorial mount. These mounts take a bit of getting used to, so we'd advise testing it out in the daytime before using it in the dark. That aperture should make it easier to spot deep-sky targets.

Orion Observer 80ST
From: Amazon
Cost: £140 / $180
We were impressed with the views we could achieve with the refractor telescope. We were able to view Jupiter with its belts and moons, Saturn with its rings and, with the right eyepieces, even the tiny blue-turquoise disks of faraway Uranus and Neptune. We were unsurprised to discover a degree of false colour, but this didn't ruin the viewing experience.

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WHAT'S IN THE SKY?

What to look out for during this observing period

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12 AUGUST
Conjunction between Moon and Saturn in Capricornus

12 AUGUST
The Moon and Saturn pass within 3°41' of each other in Capricornus

12 AUGUST
Conjunction between Moon and Mars in Taurus

13 AUGUST
The Perseids reach their peak of 150 meteors per hour

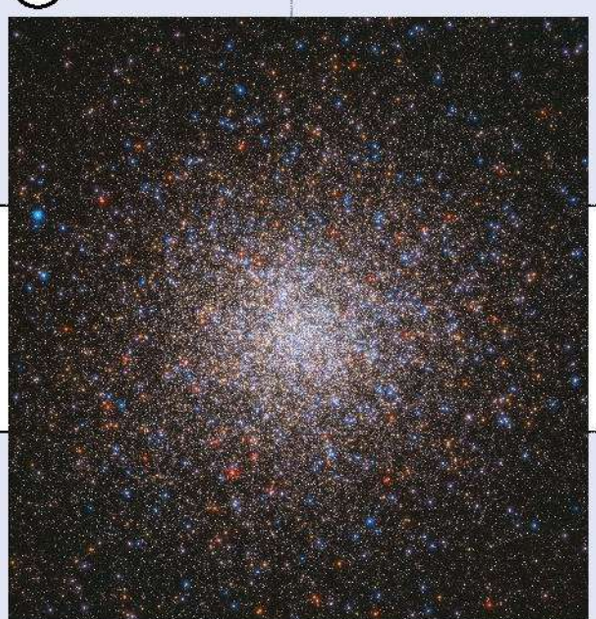
14 AUGUST
Saturn reaches opposition, dazzling at magnitude +0.3 in Capricornus

14 AUGUST
Globular cluster Messier 15 is well placed for observation in Pegasus

14 AUGUST
Globular cluster Messier 2 is well placed for observation in Aquarius

14 AUGUST
Asteroid 4 Vesta reaches opposition, glowing at magnitude +6.1 in Aquarius

15 AUGUST
The Moon and Jupiter pass within 1°51' of each other in Cetus



15 AUGUST
The Moon and Jupiter make a close approach, passing within 1°39' of each other in Cetus

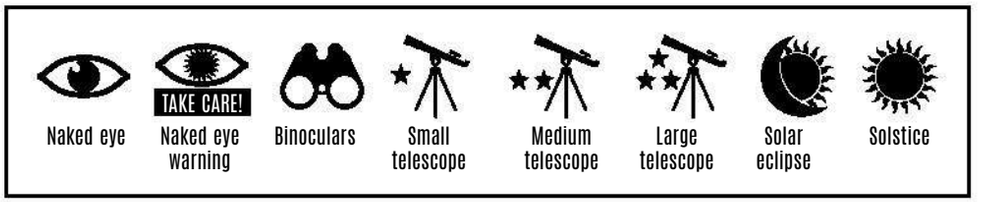
18 AUGUST
The Moon and Saturn pass within 3°43' of each other in Capricornus

24 AUGUST
Conjunction between Venus and Ceres in Cancer

27 AUGUST
Mercury is at its greatest elongation east in the evening sky

29 AUGUST
Mercury reaches half phase, or dichotomy

1 SEPTEMBER
The Aurigids reach their peak of 6 meteors per hour



18 AUGUST
The K-Cygnids reach their peak of 3 meteors per hour

19 AUGUST
The Moon and Uranus pass within 31.1 arcminutes' of each other in Taurus

25 AUGUST
Comet 73P/Schwassmann-Wachmann will make its closest approach to the Sun

8 SEPTEMBER
Conjunction between Moon and Saturn in Capricornus

18 AUGUST
The Moon and Uranus pass within 2°33' of each other in Aries

24 AUGUST
Uranus enters retrograde motion, stopping its usual eastward movement

18 AUGUST
The Moon will pass in front of Uranus, visible from parts of the United States and Kiribati

Red-light friendly
In order to preserve your night vision, you should read our observing guide under red light

Jargon buster

Conjunction
An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)
How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition
When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)
RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds, as since Earth rotates on its axis, we see different parts of the sky throughout the night.

Magnitude
An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of –1.0 is brighter than +2.0.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

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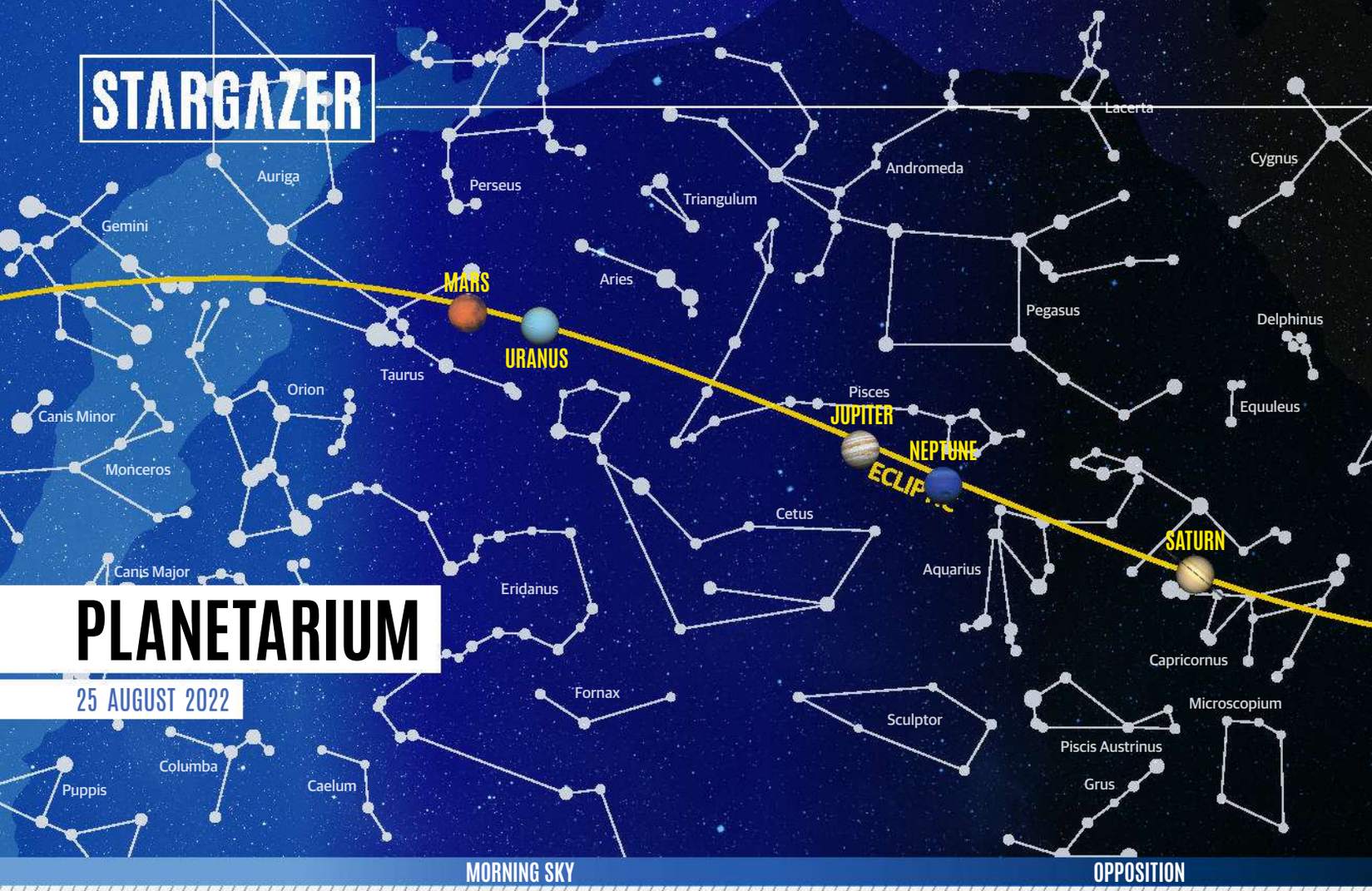


PLANETARIUM

25 AUGUST 2022

MORNING SKY

OPPOSITION

MOON CALENDAR

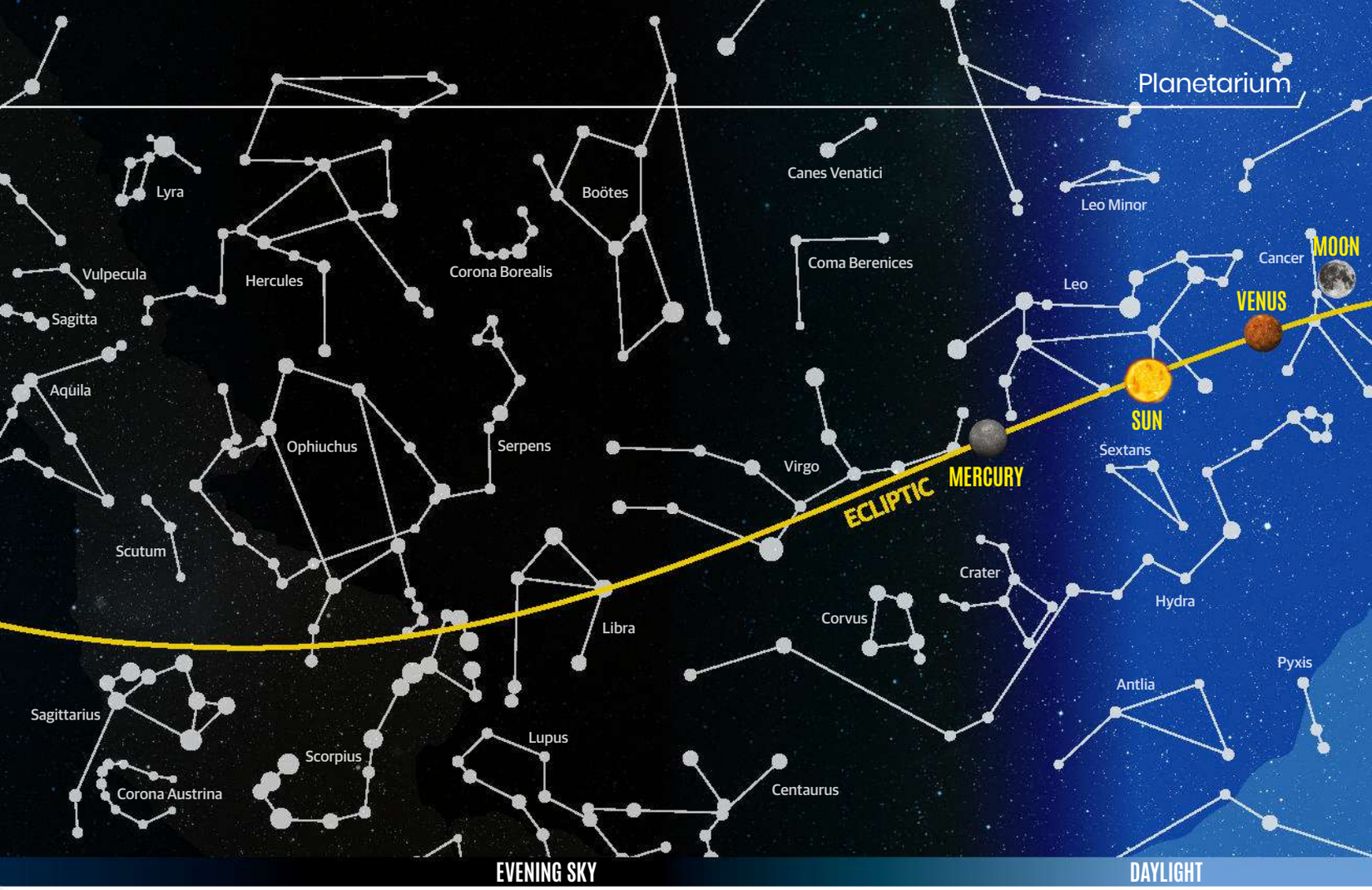
* The Moon does not pass the meridian on 9 September

11 AUG 98.0% 04:02 20:54	12 AUG 99.8% 05:34 21:18	13 AUG 98.4% 07:05 21:36	14 AUG 94.2% 08:32 21:51			
15 AUG 87.6% 09:54 22:05	16 AUG 79.3% 11:13 22:18	17 AUG 69.8% 12:31 22:33	18 AUG 59.8% 13:47 22:50	19 AUG TQ 49.6% 15:01 23:12	20 AUG 39.7% 16:12 23:41	21 AUG 30.3% 17:17 --:--
22 AUG 21.8% 00:19 18:12	23 AUG 14.3% 01:09 18:57	24 AUG 8.2% 02:09 19:30	25 AUG 3.6% 03:17 19:56	26 AUG 0.9% 04:29 20:15	27 AUG NM 0.2% 05:43 20:31	28 AUG 1.6% 06:58 20:44
29 AUG 5.1% 08:12 20:57	30 AUG 10.8% 09:27 21:09	31 AUG 18.4% 10:44 21:23	1 SEP 27.7% 12:04 21:40	2 SEP 38.4% 13:27 22:01	3 SEP FQ 49.9% 14:52 22:31	4 SEP 61.7% 16:12 23:14
5 SEP 73.1% 17:22 --:--	6 SEP 83.1% 00:15 18:15	7 SEP 91.3% 01:34 18:53	8 SEP 96.9% 03:02 19:20			

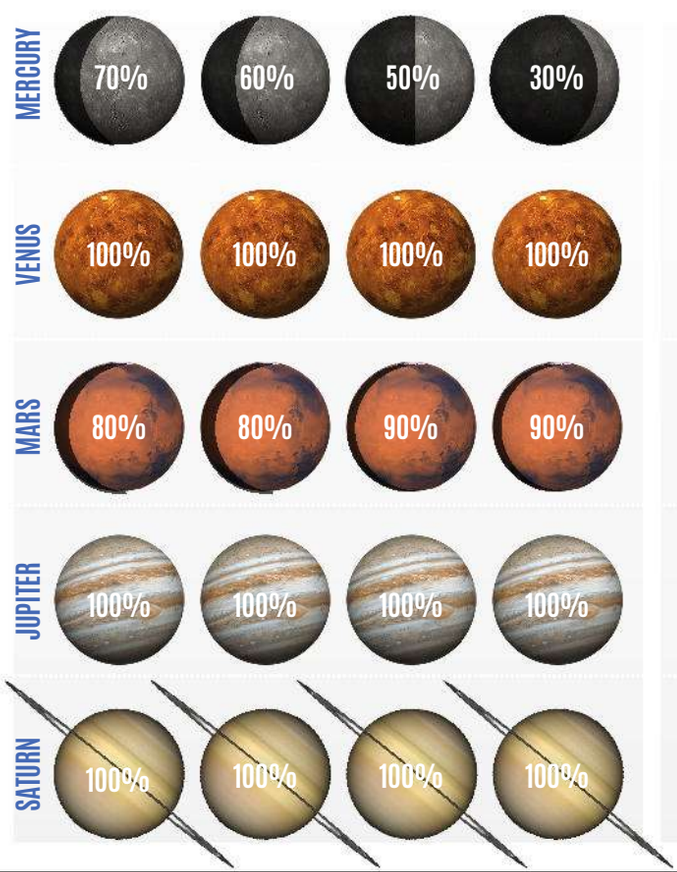
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



ILLUMINATION PERCENTAGE



PLANET POSITIONS

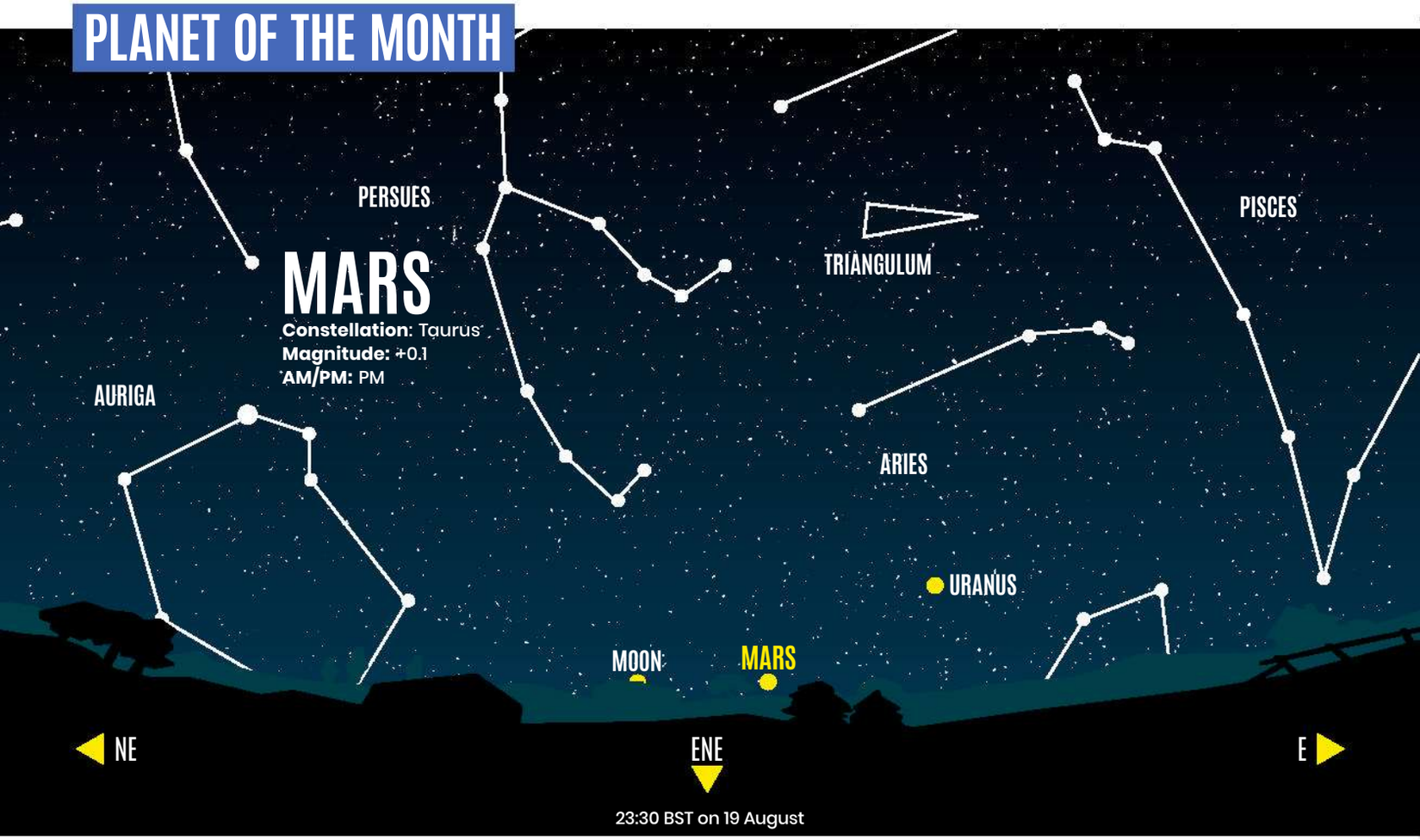
All rise and set times are given in BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
11 AUG	10h48m09s	+07°59'40"	Leo	-0.2	07:43	21:13
18 AUG	11h23m06s	+03°14'33"	Leo	0.0	08:15	20:55
25 AUG	11h51m58s	-01°05'28"	Virgo	+0.1	08:38	20:35
1 SEP	12h13m35s	-04°38'40"	Virgo	+0.3	08:50	20:11
8 SEP	12h24m43s	-06°50'18"	Virgo	+0.7	08:45	19:43
11 AUG	08h03m49s	+20°47'03"	Cancer	-3.9	03:45	19:43
18 AUG	08h39m33s	+19°04'38"	Cancer	-3.9	04:05	19:40
25 AUG	09h14m35s	+16°55'29"	Cancer	-3.9	04:25	19:34
1 SEP	09h48m50s	+14°22'54"	Leo	-3.9	04:47	19:26
8 SEP	10h22m20s	+11°30'39"	Cancer	-3.9	05:09	19:15
11 AUG	03h28m25s	+17°14'43"	Taurus	+0.1	23:33	14:46
18 AUG	03h45m40s	+18°18'30"	Taurus	0.0	23:17	14:42
25 AUG	04h02m23s	+19°14'43"	Taurus	-0.0	23:00	14:37
1 SEP	04h18m27s	+20°03'33"	Taurus	-0.1	22:43	14:31
8 SEP	05h25m03s	+22°45'40"	Taurus	+ 0.1	21:06	13:30
11 AUG	00h32m11s	+01°50'59"	Cetus	-2.8	22:01	10:27
18 AUG	00h30m51s	+01°40'22"	Cetus	-2.8	21:33	09:57
25 AUG	00h28m58s	+01°26'25"	Cetus	-2.8	21:05	09:27
1 SEP	00h26m35s	+01°09'29"	Cetus	-2.9	20:36	08:55
8 SEP	00h23m47s	+00°50'08"	Pisces	-2.9	20:08	08:23
11 AUG	21h38m40s	-15°26'42"	Capricornus	+0.3	20:38	06:04
18 AUG	21h44m25s	-14°55'21"	Capricornus	+0.4	22:03	07:35
25 AUG	21h36m37s	-15°37'24"	Capricornus	+0.3	20:10	05:33
1 SEP	21h32m38s	-15°57'39"	Capricornus	+0.3	19:13	04:32
8 SEP	21h30m47s	-16°06'43"	Capricornus	+0.4	18:40	03:58

THIS MONTH'S PLANETS

Mars prepares for opposition in the summer sky, while the gas planets will also be an easy catch in the evening

PLANET OF THE MONTH



Mars might be a frozen dustball of a planet, but it's warming up nicely for its Opposition at the end of the year, when it will be very close to Earth and very bright in our night sky, too.

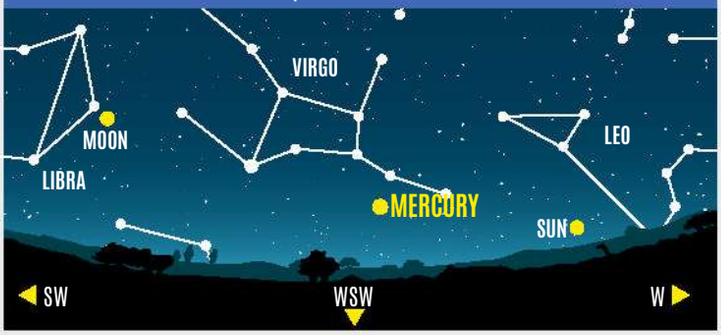
During the month ahead, the famous Red Planet – which is actually more of a mandarin orange colour when you see it in the sky – will be obvious to the naked eye, looking like a bright 'star' in the constellation of Taurus. You won't have any trouble identifying it because, with a magnitude of 0.1, it will be brighter than any of the stars in that constellation, even Aldebaran, which is the brightest. At the start of our observing period, Mars will be rising in the north east at around 11:30pm, which just about qualifies it as an evening object.

During mid-August, you will find Mars shining on the edge of Taurus, eight degrees to the lower right of the famous 'Pleiades' star cluster, and less than six degrees from much fainter Uranus, but it will quickly pull away from that distant, green-hued world and move towards the 'Morning Star; Venus in the pre-dawn sky, brightening as it does so.

By 1 September, Mars will have moved further into Taurus and be shining between the Pleiades and the V-shaped Hyades cluster below it, and sweeping that area with binoculars will show you ruddy Mars surrounded by many blue, white and silver stars. By then, Mars will have brightened to magnitude -0.1, and will be very striking to the naked eye once the sky has darkened.

By 8 September, Mars will be less than four degrees away from Aldebaran, and the two will look lovely together through binoculars, providing a fascinating contrast of colours. During mid- to late-August, Mars will be approached and then passed by the Moon, which will also be fascinating to watch. On 19 August, the Last Quarter Moon will be shining to the planet's right, and on the following evening the Moon will have moved eastwards to take up position to the left of Mars.

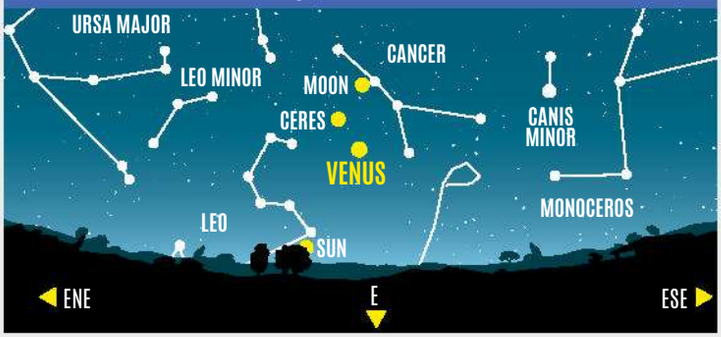
MERCURY 19:30 BST on 1 September



Constellation: Leo **Magnitude:** -0.1 **AM/PM:** PM

If you're a fan of Mercury then this will not be a good month for you. At the start of our observing period it is so close to the Sun in the evening sky that it will be setting just 20 minutes after it, so finding it in the post-sunset glare will be almost impossible. By 1 September, Mercury and the Sun will set simultaneously, so it won't be visible.

VENUS 06:30 BST on 25 August



Constellation: Cancer **Magnitude:** -3.9 **AM/PM:** AM

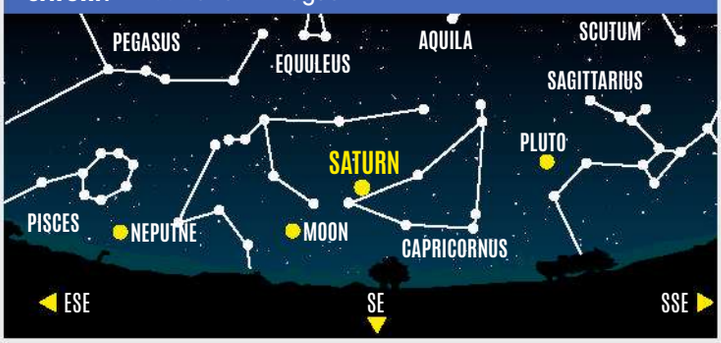
In mid-August, Venus will rise two hours before the Sun, climbing up to become a spark – you won't be able to miss it. However, as August progresses, Venus's visibility will worsen as it falls back towards the Sun. In the first week of September, Venus will pass Regulus, Leo's brightest star. By 11 September, Venus will rise an hour before the Sun.

JUPITER 22:30 BST on 15 August

Constellation: Pisces **Magnitude:** -2.7 **AM/PM:** PM

At the start, Jupiter is in Cetus, which isn't one of the dozen 'Zodiacal' constellations the Sun, Moon and planets usually move through. It soon moves into Pisces, where it will be visible as a bright star, rising around 10pm. The best time to see this will be around midnight, when it will be high above the south-eastern horizon.

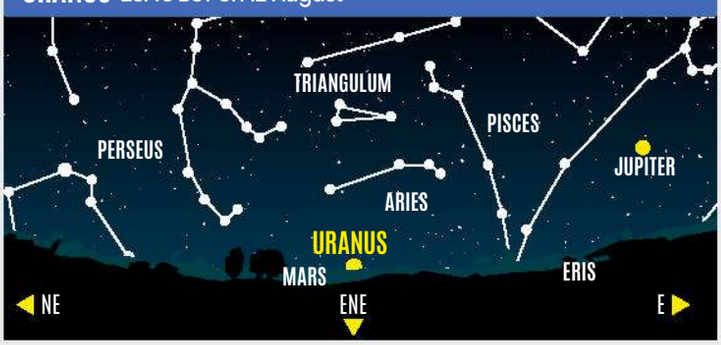
SATURN 22:00 BST on 12 August



Constellation: Capricornus **Magnitude:** +0.3 **AM/PM:** PM

Saturn will rise around 9pm, but won't be clearly visible for at least half an hour. By 9.30pm you'll be able to see it as a yellow-white star low in the south-east, and by midnight it will be high enough to stand out from the rest of the stars around it. As the days pass, Saturn will rise earlier until by 8 September it is rising before sunset.

URANUS 23:45 BST on 12 August



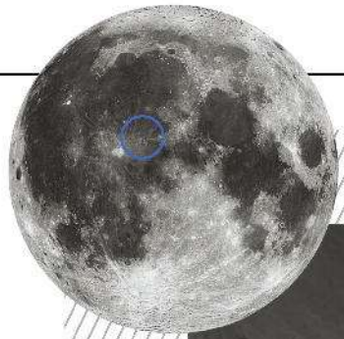
Constellation: Aries **Magnitude:** +5.8 **AM/PM:** PM

Shining at magnitude 5.8, Uranus will technically be a naked eye object, but unless you have near perfect eyesight, you'll need binoculars and a star chart to identify it. It will start the month six degrees away from Mars, but the two will move apart quickly. It will also help that Uranus has a pale but distinctive green colour.

NEPTUNE 23:45 BST on 12 August

Constellation: Pisces **Magnitude:** +7.8 **AM/PM:** PM

Neptune is the most distant planet in our Solar System, and also the faintest. Shining at magnitude 7.8, it can't be seen by the naked eye, so you'll need binoculars or a telescope, and a really good finder chart, to track it down. At the end of our observing period, Neptune will move into Aquarius, just under 12 degrees to the west of Jupiter.



MOON TOUR

ERATOSTHENES CRATER

Make the most of this well-defined asteroid impact

Eratosthenes is a 59-kilometre (37-mile) wide crater located at the western end of the majestic curved sweep of the lunar Apennine Mountains (Montes Apenninus) on the southern shore of Mare Imbrium (Sea of Rains). This magnificent crater, set among a splendid mountain backdrop, is often overlooked by virtue of its proximity to the larger crater Copernicus, which is 93 kilometres (58 miles) wide and lies less than 300 kilometres (186 miles) to the southwest of Eratosthenes, so is often visible at the same time. However, Eratosthenes itself is such a spectacular feature when illuminated by a morning or evening Sun that its topography is delightful through mid to high magnifications.

Eratosthenes is a typical mid-sized lunar impact crater, and its prominence is accentuated by its startling position at the southern end of the lunar Apennine Mountains. Formed by an asteroid collision less than 2 billion years ago, Eratosthenes is around 1 billion years older than its near-neighbour Copernicus. As Eratosthenes first becomes illuminated by an early morning Sun – around a day after first quarter on average – the magnificent mountain arc preceding it forms a beautiful frame to the southern margin of Mare Imbrium.

When illuminated by a low morning or evening Sun, a prominent system of concentric and radial impact ridges shows up well around Eratosthenes. Owing to the crater's great age, much of the external sculpting around the crater has been hidden by later lava flooding by Mare Imbrium to its north and Sinus Aestuum (Seething Bay) to its south, but a fair amount of impact topography remains to be seen through relatively small instruments under a low Sun. Eratosthenes' floor displays a central mountain massif surrounded by a hummocky landscape that is stained with numerous dark spots and other variations in albedo. Unusually for such a large formation, Eratosthenes is barely visible under high angles of illumination – the crater's wall vanishes more or less completely, but its central peaks and dusky floor patches can be discerned at local lunar midday.

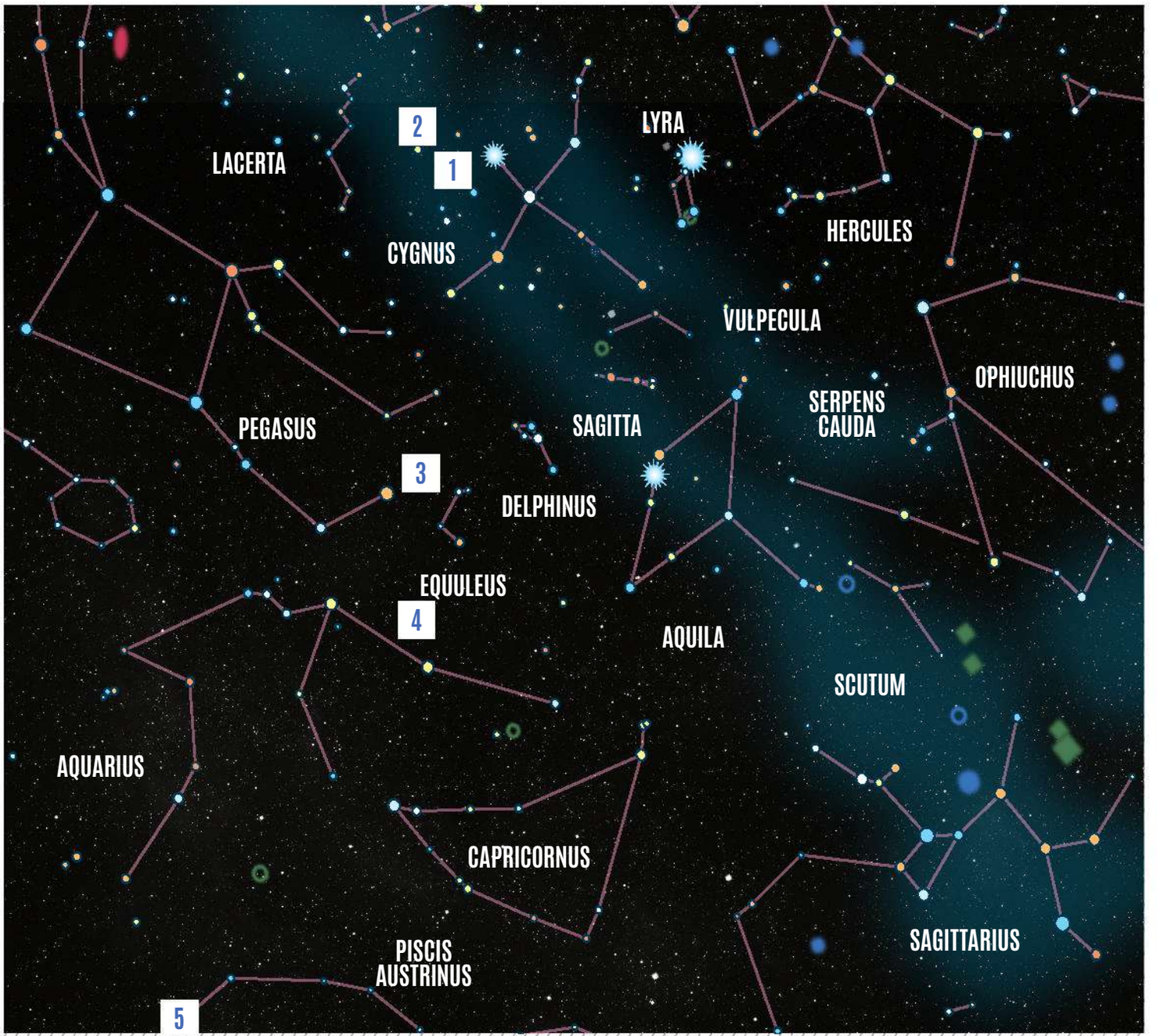
A century ago, Eratosthenes attained a certain amount of notoriety through the observations and opinions of astronomer William Henry Pickering, who observed Eratosthenes many times between 1919 and 1924. His vivid imagination convinced him that the dark spots on the crater's floor vary in intensity, and in addition the spots seemed to move around throughout the lunar day. Pickering, a fan of life on the Moon, speculated that the dark patches were due to the presence of vast swarms of lunar insects or herds of small animals constantly on the move, crawling or hopping around in search of sustenance. In reality, the spots on Eratosthenes' floor are composed of dusky surface material and are as motionless as its central peak. The patches do vary in their apparent tone, but so do countless other albedo features in response to the changing angle of sunlight.

Eratosthenes will be illuminated on 5 September, and you may just be able to locate the crater to the northeast of Copernicus, embedded within the impact rays of the larger, more famous crater – but the lack of shadows means that this is not an easy identification for a first-time observer. The lunar sunset terminator then moves slowly from the east during the following days, and hints of topographic detail within Eratosthenes gradually reveal themselves as the shadows deepen. By 17 September the lunar morning terminator is encroaching upon Eratosthenes and the crater makes for a really splendid sight, preceding the mighty Copernicus on the sunrise terminator to its west.

Source: Wikipedia Commons © Exoexo

TOP TIP!

On the morning of 26 August, the lunar morning terminator will be encroaching upon Eratosthenes, with the crater making for a splendid sight. A Moon filter will improve contrast, toning down any glare that washes out intricate features of the lunar surface.



NAKED EYE AND BINOCULAR TARGETS

Summer skies are full of celestial wonders, particularly in Cygnus and Aquarius

1 North America Nebula
Lying just to the east of the bright star Deneb, this large region of ionised gas is just visible with binoculars from a dark-sky site.

2 Messier 39
Just north of the North America Nebula, Messier 39 is just visible to the naked eye and a superb target through decent binoculars.

3 Messier 15
Lying just on the edge of naked-eye visibility, this globular star cluster looks like a fuzzy ball of light in 10x50 binoculars.

4 Messier 2
Similar to Messier 15, this globular cluster is just on the limit of naked-eye visibility. It has some of the oldest stars in the universe.

5 Fomalhaut
This is a bright star of the Southern Hemisphere that is visible in much of the north, but only for a short time.

1 The Veil Nebula

DEEP SKY CHALLENGE

DIVING DEEP INTO THE SUMMER SKY

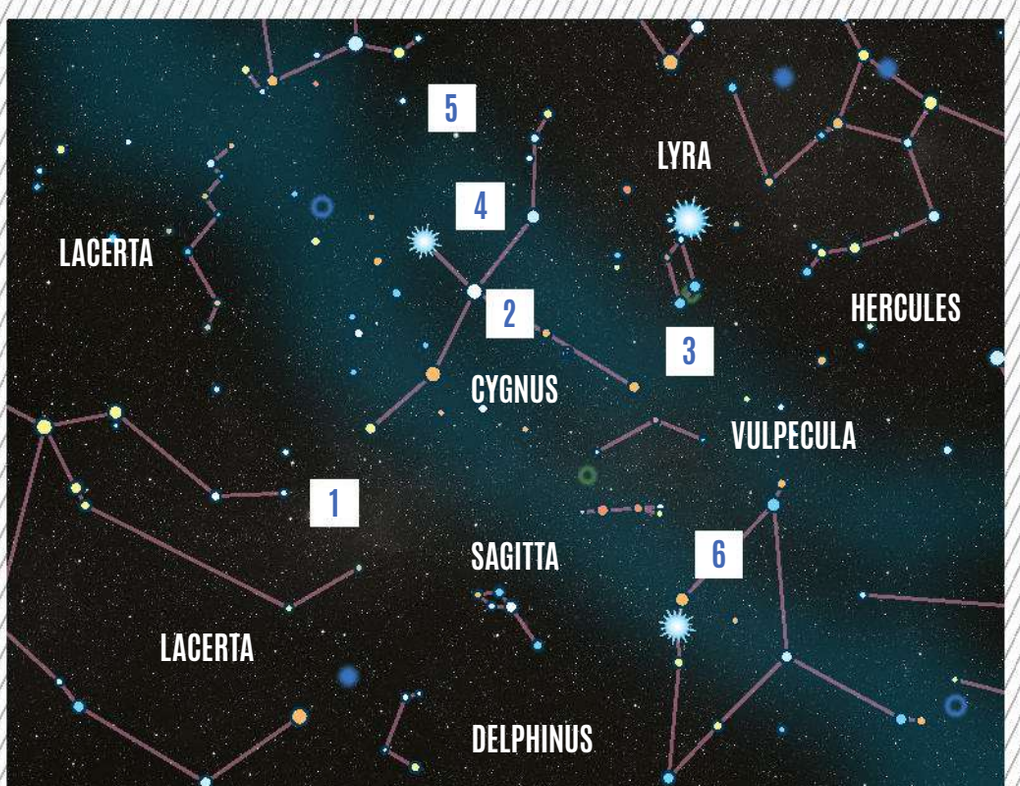
Find the ghostly remains of dead stars, glittering ancient star clusters and a spectacular distant galaxy

Astronomy is, very generally speaking, the study of stars and everything to do with them – how they are born, live and die; how they work; the objects that go around them and much more. The sky in August and September offers the naked-eye observer some of the most beautiful stars in the sky and the mottled band of the Milky Way, too, itself made out of countless billions of stars.

But beyond the stars, through their misty veil, lie objects that are as fascinating as they are faint and as beautiful as they are subtle. Four of our six challenging deep-sky objects this month are nebulae, one is a distant glittering star cluster and the sixth is another galaxy altogether, an elegant Catherine wheel of stars far beyond the boundary of our own Milky Way. All these objects are going to be a challenge for you if you live somewhere that isn't blessed with a dark sky – and a couple require a large telescope to see them – but they're all worth looking for.

The ghostly curled wisps of the Veil Nebula are all that remains of a once-mighty star that blew up millennia ago. NGC 6946 is a tightly wound spiral galaxy positively popping and fizzing with star formation. Messier 56 is one of the faintest objects in Messier's famous catalogue – an enormous ball of perhaps a million stars, reduced in a telescope eyepiece to a tiny, smoky ball by its incredible distance. All you need now is a clear night for prime viewing.

5 The Fireworks Galaxy



1 The Veil Nebula

The ghostly remains of a star that blew up around 8,000 years ago, the Veil Nebula is fifth magnitude but is so large and diffuse you'll need a good telescope and a dark sky to see its faint misty arcs.

2 The Crescent Nebula (NGC 6888)

This magnitude +7.4 emission nebula has a distinctive crescent shape in a low-power eyepiece. Around 5,000 light years away, the nebula is best seen using averted vision.

3 Messier 56

One of the faintest globular clusters in Messier's catalogue, magnitude +8.3 Messier 56 can be resolved almost to its centre through a telescope's high-power eyepiece.

4 The Blinking Nebula (NGC 6826)

This magnitude +8.9 planetary nebula looks like a small blue-green oval in a large telescope. Looking at and then away from its central star makes the nebula appear to blink on and off.

5 The Fireworks Galaxy (NGC 6946)

The curved arms of this beautiful face-on spiral galaxy are best seen through the high-power eyepiece of a large telescope. The galaxy is ablaze with colourful areas of star formation.

6 NGC 6803

At magnitude +11.5, this planetary nebula is so faint you'll need a large telescope under a very dark sky to see its tiny pale-blue disc. It's more than 6,000 light years away from Earth.

"These are going to be a challenge somewhere that isn't blessed with a dark sky"

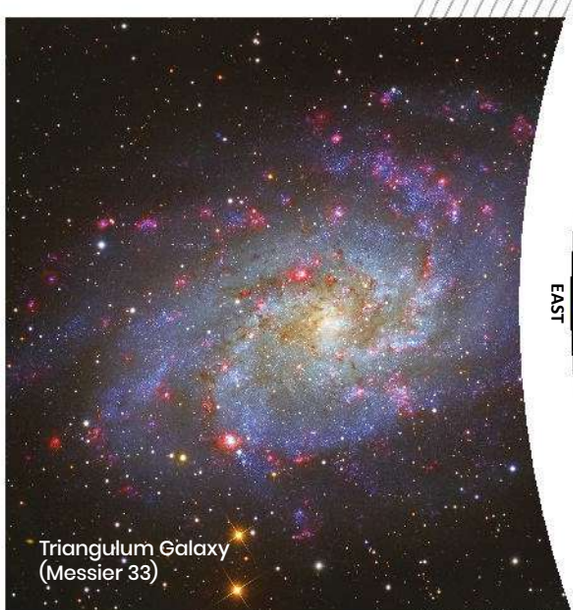
© NASA; ESA; JPL-Caltech; Source:Wikipedia Commons; Göran Nilsson & The Liverpool Telescope

THE NORTHERN HEMISPHERE

Galaxies and globular clusters are easy pickings with binoculars and telescopes

As we head into late summer, the night sky is alive with a worthy selection of deep-sky objects, in particular galaxies and star clusters. Starburst galaxy Messier 82, also known as the Cigar Galaxy, spiral galaxy Messier 106 as well as neighbouring spiral Messier 94 all offer splendid views. Star clusters such as Messier 10, Messier 12 and Messier 14 are ideal for those who aren't looking to stay up too late. But for those keen to stay up into the early hours of the morning, the galaxies of the constellations of Andromeda and Triangulum wheel into view, as well as a variety of open and globular star clusters which are visible in a range of instruments.

Messier 94


Triangulum Galaxy (Messier 33)

Messier 81 Group

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

Magnitudes

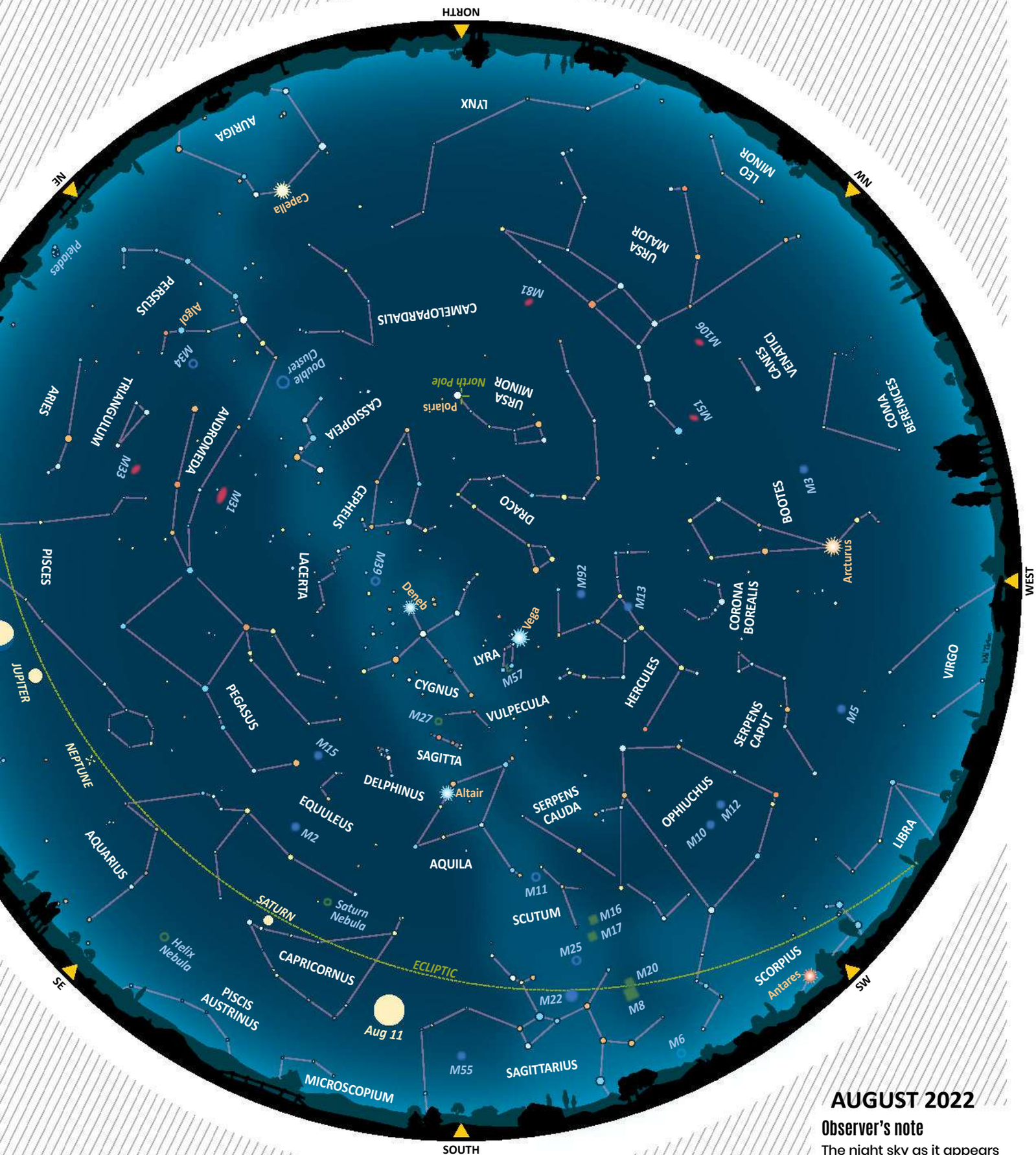
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- O B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



AUGUST 2022

Observer's note

The night sky as it appears on 17 August 2022 at approximately 22:00 (BST)

© Getty

ASTROSHOTS OF THE MONTH

TERRY HANCOCK

Location: Colorado

Telescope: Takahashi FSQ-130ED

"The California Nebula (NGC 1499) captured in narrowband using the new QHY600 60-megapixel full-frame monochrome CMOS camera mounted on the Takahashi 130 FSQ. In this Hubble Palette version the H-Alpha is mapped to green, SII is mapped to red and OIII is mapped to the blue channel. While the colours in this image are not true, the narrowband filters used in the making of this Hubble Palette image reveal much more of the hidden gases not visible in a broadband image. I captured this over five nights for a total acquisition time of 11.6 hours."

California Nebula (NGC 1499)

Lagoon Nebula (Messier 8) and Trifid Nebula (Messier 20)

BASUDEB CHAKRABARTI

Location: Heaven's Mirror Observatory, Australia

Telescope: Takahashi FSQ-106ED

"The Lagoon Nebula (Messier 8) and Trifid Nebula (Messier 20), combined are a giant interstellar cloud in the northwest of Sagittarius in a star-forming region in the Milky Way's Scutum-Centaurus Arm. They are classified as an emission nebula and as an H II region. The Lagoon Nebula is estimated to be between 4,000 and 6,000 light years away from Earth. In the sky of Earth it spans 90 by 40 arcminutes, which translates to an actual dimension of 110 by 50 light years. The nebula contains a number of Bok globules. The Lagoon Nebula also contains a structure at its centre known as the Hourglass Nebula. The Trifid Nebula is an unusual combination of an open cluster of stars, an emission nebula, reflection nebula and dark nebula."

JASPAL CHADHA

Location: London

Telescope: Celestron C11 HD Edge

"I have been imaging for around two-and-a-half years now after spending years looking through various telescopes and eyepieces, where I enjoyed learning all about the objects in the night sky. After months of research and trial and error, I finally invested in a set-up that I thought would work for me. My biggest challenge has been to fend off the myths around imaging in light-polluted areas, as I live in London. I started out with DSLR astrophotography but now use a CCD to capture a wide range of night-sky targets."

Messier 92

REVIEW

MOVE SHOOT MOVE STAR TRACKER

A perfect place to start for aspiring astrophotographers, but how does it hold up in real life?

Reviewed by Dave Stephenson

At just £205.99 ($249), the Move Shoot Move star tracker is more or less the cheapest star tracker on the market. Weighing in at only 450 grams, it's also one of the lightest, allowing fleet-footed astrophotographers to bring it with them even if weight is a consideration. But with other entry-level star trackers coming in at nearly double the price, the hunt for compromises is on: how does the Move Shoot Move stack up against the competition?

The Move Shoot Move star tracker is a compact little thing, which forms a huge part of its appeal. Compare it to the likes of the Sky-Watcher Star Adventurer 2 – pricier, but admittedly with a few more talents – and you'll see what we mean. The Move Shoot Move tips the scales at just 450 grams, which combined with its size of 4.3 by 8.1 by 9.9 centimetres (1.7 by 3.2 by 3.9 inches) makes it genuinely pocketable.

It has a simple-looking design. Made of tough-feeling metal, the top disc – the bit that rotates – has a grippy circle of rubber on it to minimise slipping, while the front has just two buttons. One powers the unit on and off and can also be used to let it know which hemisphere of Earth it's in, while the other varies how quickly the Move Shoot Move star tracker rotates. You get the option of what we came to call 'normal', in which the Move Shoot Move matches the rotation of Earth for steady long exposures, and half-speed, which allows much longer rather than theoretically indefinite wide-angle exposures of the Milky Way. There's also the option to set the Move Shoot Move up to provide 0.125, 0.1, 0.075 and 0.05 degrees of movement, allowing you to shoot time-lapses with rotations in between them.

There are a pair of 2.5mm ports on one edge: one for connecting a camera so the Move Shoot Move can shoot its own images and the other for connecting to a slider, allowing the slider to direct the Move Shoot Move to both turn and shoot. Finally, there's a USB-C port on the other side for charging. Usefully, the Move Shoot Move can continue working while it's being charged, so if you find yourself low on juice you can always connect it to a power bank. In fairness, Move Shoot Move claims five hours of continuous rotation will probably be more than enough – that's 60 five-minute exposures.

Also in the bag, before you've bought a few essential accessories, you get a hot shoe trigger cable so the Move Shoot Move can communicate with your camera when it's in time-lapse mode, a set of Allen keys and a pair of brass tripod studs. The bag itself is worth a mention – its sturdy-feeling fabric makes it a reassuring place to store such a precision piece of kit.

Once you come to use the Move Shoot Move, or ideally before given it involves accessories being ordered and delivered, you'll realise that the price isn't the whole story. You'll need a laser at least: using any star tracker requires you to be aligned with Polaris, the North Star, which on wide-angle lenses can be done accurately enough with a powerful laser pointer. You can upgrade to a bundled Move Shoot Move and pointer for £230.99 ($279), which usefully comes with a rechargeable battery.

You'll also need a tripod head. Using the Move Shoot Move at all

It's small and portable for astro on the go

STAR TRACKER ADVICE

Cost: From £205.99 / $249

From: Move Shoot Move

Dimensions: 4.3 by 8.1 by 9.9 centimetres (1.7 by 3.2 by 3.9 inches)

Weight: 450 grams

Connection type: USB-C for charging, 2.5mm for camera connection, 2.5mm connection for slider

Battery life: Five hours rotation or 3,000 shots

BEST FOR...

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- INTERMEDIATE
- SKYSCAPES
- WIDE-FIELD ASTROPHOTOGRAPHY

We recommend buying the tracker with the pointer

requires two tripod heads: one on your actual tripod, to which the Move Shoot Move is mounted, and then another screwed to the top of the Move Shoot Move, on which your camera is placed. Don't do what the economically minded team at **All About Space** tried and use two ball heads. Getting a ball head tripod mount lined up with the North Star – a pinprick of light some 400 light years away, although not impossible, is sufficiently hard enough that most of the fun of astrophotography is instantly whisked away. We had success with Move Shoot Move's own geared tripod head, again bundled with the tracker for a bit extra, which mounts to your Move Shoot Move rotator and allows very precise adjustment.

It's an impressive piece of kit – even with a Canon EOS R6 and Sigma's heavy 14mm f/2.8 ART lens attached, turning the screws still yielded accurate movement and made getting the Move Shoot Move initially lined up much easier. If you don't have a wedge already, do yourself a favour and pop this in your shopping basket. It's likely any precision-made, geared tripod head will do the trick. Immediately, you can see that the true price of the Move Shoot Move, the amount you need to spend to be able to actually use the tracker – starting from zero previously owned astrophotography kit – is much higher than the base price. Ordering the complete bundle will set you back £395.99 ($479), which brings the Move Shoot Move much closer in price to bigger, heavier entry-level star trackers. Still, saving money is saving money, so we're prepared to forgive the Move Shoot Move if it actually works.

Setting up is a touch fiddly, although this lines up with the experience of setting up any star tracker. A bit of experience comes in handy, so just as you would any other bit of new, specialist kit, we'd suggest at least a couple of familiarisation runs before you head out on the once-in-a-lifetime trip. There's a bit of assembly needed first – the brass 9.5mm screw that goes in the middle of the tracker; then you need to attach a tripod plate to one of the 6.35mm screw holes. Which hole you choose will depend a little on exactly what kind of composition you want.

The laser pointer is simple in theory – attach it to the side of the Move Shoot Move and point it at Polaris, then adjust your tripod head until it, and essentially the Move Shoot Move rotator, are pointing straight there. The laser is a simple one-button job, although you can adjust its beam for better accuracy. It comes with a rechargeable lithium-ion battery rated at 280mAh, which gave us several nights' use on a single charge.

We did notice a recommendation in the manual that the laser is not run for more than 30 seconds at a time; we definitely powered it for a little longer than that on a few of our more laborious efforts to get the Move Shoot Move lined up with Polaris, but given that the power button is a single push,

we stored the battery outside the laser to prevent it accidentally turning on.

Once the rotator is lined up, you can mount your camera to it and adjust your camera's ball head until you've got the composition you want. Double-check polar alignment and suddenly the sky becomes a playground. If your composition is of just stars, you can simply power the unit up and start shooting as it starts turning immediately. If you want to create a blended exposure with a static foreground and bright background stars, you can shoot your static composition first, then start the Move Shoot Move and begin a longer exposure, compositing the two later.

Use is incredibly simple from this point on: turn on the Move Shoot Move and it starts turning, allowing you to shoot as many long exposures as you like without worrying about how your stars are composed. There are complexities, of course, although these aren't unique to the Move Shoot Move. That car that drove past a mile away? Light pollution. That gust of wind halfway through your shot? Ruined sharpness. But we did find that the Move Shoot Move was a reliable unit. Using our 14mm lens we were able to get shots up to five minutes – we didn't need any longer – and on our longer 24mm lens three minutes or so was the longest reliable mark we could hit. We got sharp frames at longer exposures than that, but they were a bit hit and miss. Ultimately, though, the experience of shooting long exposures that aren't ruined by noise is what any star tracker is about, and if you're shooting wider lenses the Move Shoot Move could well be the only tracker you ever need.

Once the Move Shoot Move star tracker is set up and turning, there's not a lot to think about. We worked out what our shutter speed should be by shooting an ultra-high ISO shot at first just to get a baseline, then worked backwards, removing ISO and adding shutter speed in equal measure until we had a suitably low ISO and a shutter speed that worked for us.

Unequivocally, the Move Shoot Move star tracker works, and impressively well at that. We found that ultra-long exposures of four minutes or more gave us quite hit-and-miss results, but that's less because the Move Shoot Move is inaccurate and more because a lot can go wrong in four minutes. A gust of wind, a passing car or someone walking too close to your tripod can all add up to a ruined exposure. We found very reliable exposures around the three-minute mark on a succession of excellent Sigma astrophotography lenses – the 14mm f/1.8 ART, the 20mm f/1.4 ART and the 14-24mm f/2.8 ART.

The makers of the Move Shoot Move make some impressive claims about its capacity, chief among them that it can hold – and more importantly work – with up to three kilograms of kit on top of it. That puts you firmly in the ballpark of cameras such as the Canon EOS 1D-X Mark III, complete with something like Sigma's 1.2 kilogram 14mm f/1.8 ART lens mounted to it.

It's not perfect; if the Move Shoot Move tracker was mounted a little sideways and then our camera was rigged sideways on top of that, we occasionally found that our camera would slip on top of the rotating disc on the top of the tracker, with predictably poor photographic results. In particular, although our 70-200mm f/2.8 lens undoubtedly sits within the Move Shoot Move's theoretical maximum payload, anything but a truly flat composition saw it slipping on the rotating disc. We found smaller, lighter, shorter lenses were the ones that shot sharp stars most reliably.

We can't think of a more compact or portable star tracker. In terms of carrying capacity, the Move Shoot Move is definitely at the low end. Three kilograms is impressive, but there are plenty of star trackers, albeit normally more expensive ones, that will take more. Certainly, our experiments with longer lenses suggest that if you want to shoot deep-field astrophotography a sturdier star tracker is the way to go, and that goes double if you want to shoot using a telescope and a DSLR adapter.

But if you're happy with comparatively short lenses and simply want wide-field astrophotography at a reasonably affordable price – remembering to factor in a proper tripod head and the laser pointer – the Move Shoot Move star tracker is an almost absurdly portable little gizmo that you'll easily be able to justify throwing into a bag if you're going somewhere with a promisingly dark sky and some interesting wide-angle compositions. For longer lens photography you'll outgrow the Move Shoot Move very quickly, particularly if you have grand deep-field ambitions, which is where the likes of the Sky-Watcher Star Adventurer 2i or even bigger star trackers come in. But if you want to whet your astrophotography whistle, this is a cheap, portable and easy-to-use way in.

Different degree of movement settings can be chosen

FOR

- Small and light
- Affordable price point
- Excellent battery life

AGAINST

- Doesn't work well with longer lenses
- Need additional gear to maximise potential
- Can be tricky to set up

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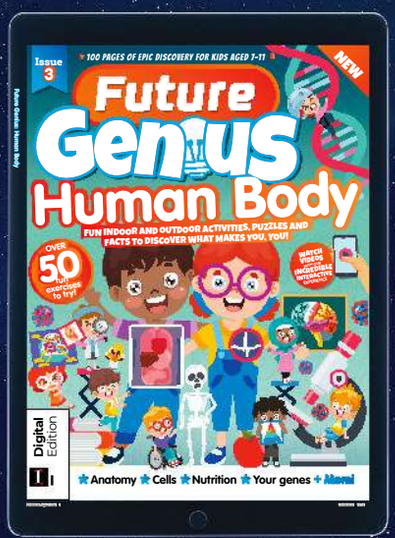
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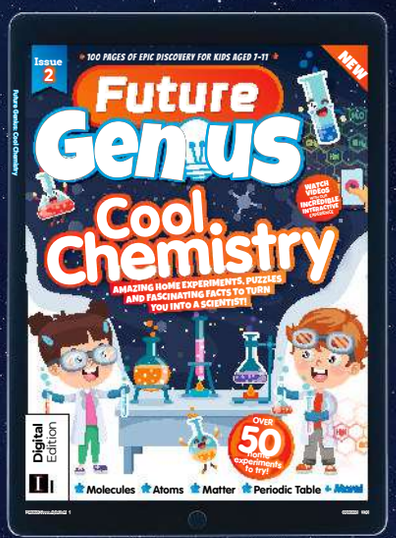
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IN THE SHOPS: LEGO SETS

Pick your next set from this excellent space-themed selection

Space Shuttle Discovery

Cost: £159.99 / $199.95
From: Lego

1 If you're a space fan, then there's no denying that this Lego NASA Space Shuttle Discovery is one of the best Lego space sets you can get your hands on right now. It's an authentic recreation of NASA's real Discovery shuttle, featuring realistic elements such as an opening payload bay, retractable landing gear, and five seats for the crew.

Unfortunately, you'll have to use your imagination there since this set doesn't come with minifigures, but it's a small price to pay for something that's otherwise so detailed. As an added bonus, it also includes a model of the Hubble Telescope, which can be handily stowed away inside the shuttle's payload bay.

Rocket Launch Center

Cost: £124.99 / $149.99
From: Lego

2 This set, along with the three to follow, is brand new and so we haven't had a chance to get hands-on with it yet. It's a replacement to Deep Space Rocket and Launch Control (60228), which was recently retired by Lego.

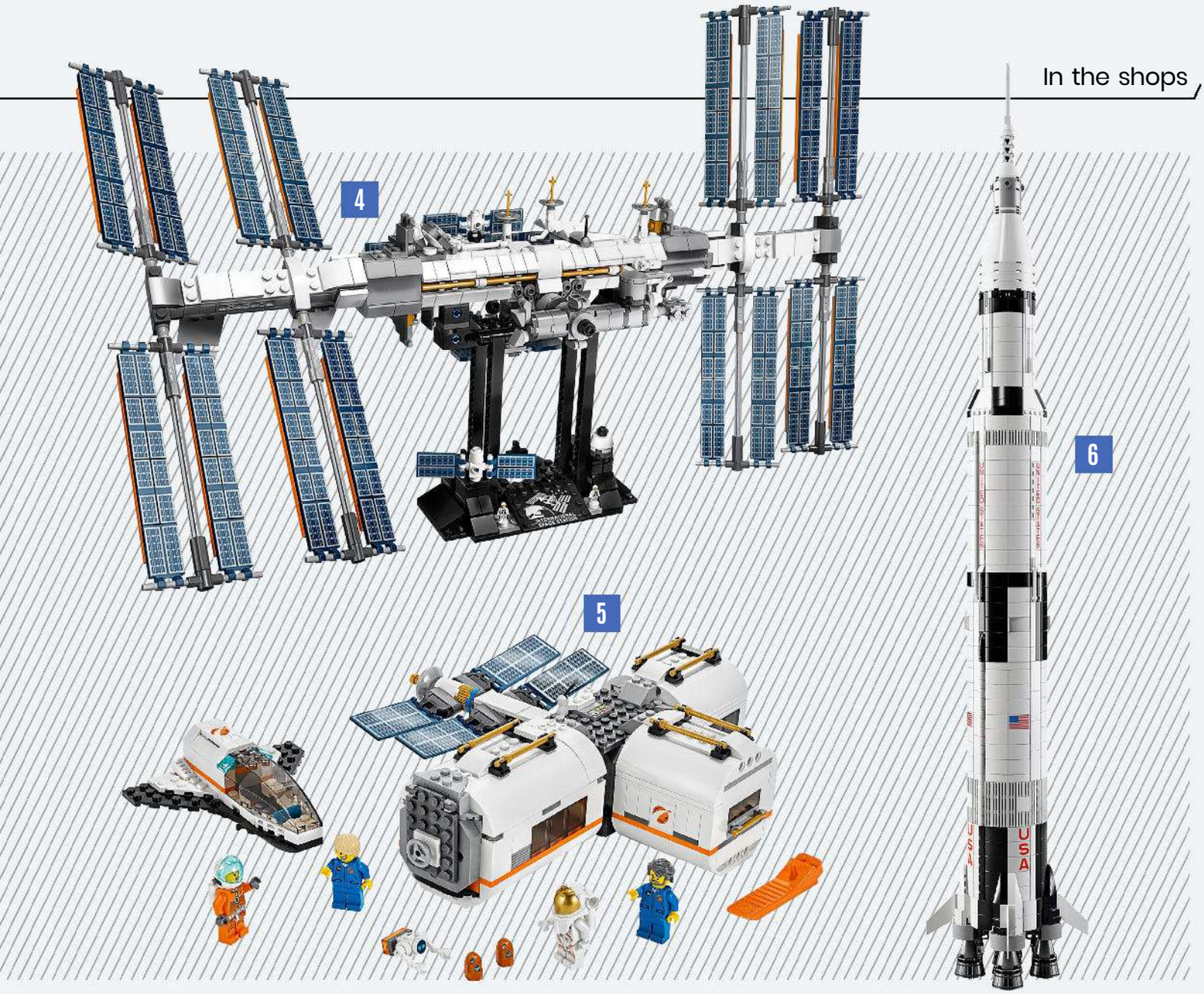
Still, you do get a lot included for that price, including a realistic rocket inspired by Artemis, NASA's return to the Moon. There's also a nice selection of minifigures: six in total, including astronauts, scientists and workmen. There's basically everything here a kid needs to stage their own rocket launch.

NASA Apollo 11 Lunar Lander

Cost: £89.99 / $99.99
From: Lego

3 Lego has spared almost no detail in bringing the Apollo 11 to life, looking as close to the real thing as a set of plastic bricks could allow. The result is a wonderful display piece, capturing the moment that humans stepped on the Moon back in 1969 brilliantly. The lander itself is expertly crafted, although the intricacy of the model means there are a few fiddly parts. It's also a little disappointing that some of the decorations are stickers rather than printed bricks.

It's not quite enough to stop this being one of the best Lego space sets out there, though. We particularly love the included display base, designed to replicate the surface of the Moon – even complete with little minifigure footprints!



International Space Station

Cost: £59.99 / $69.99
From: Lego

4 When Lego first announced the International Space Station (ISS) – a fan-designed model from the Lego Ideas range – we were a little concerned. Why? Well, it seemed that all of those solar panels could all be stickers. Thankfully, there isn't a single sticker to be seen on this model.

What is to be seen, though, is a glorious replica of the ISS, squeezing in more details than we could have imagined. Real-life features, such as the Integrated Truss Structure, habitation modules and logistics carriers have been faithfully recreated. Putting the solar panels together is repetitive though, and by their very nature they're a little flimsy and easily knocked out of place. But when it's all built, this is very impressive.

Lunar Space Station

Cost: £54.99 / $79.95
From: Lego

5 Another of Lego's newest space sets. This Lunar Space Station is based on NASA's Artemis Lunar Gateway, which gives some educational value to its play. And indeed, there's a lot to like here, including the realistic docking capsule, the science and botany labs, and the separate sleeping quarters. You can almost imagine it floating through space.

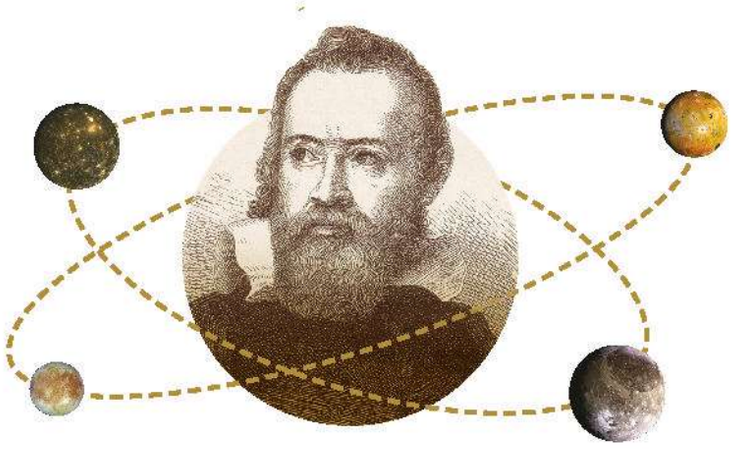
Our only concern is that it's only $10/£5 cheaper than the ultra-realistic International Space Station model. Still, this one is minifigure-scale, so for younger Lego space fans it has much more playability.

NASA Apollo Saturn V

Cost: £104.99 / $119.99
From: Lego

6 The Lego NASA Apollo Saturn V is an interesting set. It was first released in 2017 as part of the Lego Ideas range, but after being discontinued at the end of 2019, it was brought back in 2020 – the exact same product, but just with a different model number. Clearly, it was so popular that Lego decided it was worth keeping on the shelves much longer than a set's usual shelf life. And it's not hard to see why. This replica of Apollo Saturn V is incredibly detailed and epic in scale – it's a metre tall!

For space fans, too, there's an awful lot of realistic detail thrown in, such as fuel tanks, rocket fins and engines. Inevitably, the build is a little repetitive, but for something so magnificent, it's worth it.



GALILEO GALILEI

The father of modern astronomy provided the basis for our understanding of the Solar System

Italian astronomer, mathematician and physicist Galileo Galilei was born on 15 February 1564 in Pisa, Italy. He is often referred to as the father of modern observational astronomy due to his pioneering telescopic work. Vilified for supporting heliocentrism, he is one of the most important figures in the history of astronomy.

The eldest of seven children, Galileo was encouraged by his father, a musician and wool trader, to study medicine. Eventually, despite flirtations with becoming a monk – to which his father objected – he enrolled at the University of Pisa at the age of 17 to study medicine. At the age of 20, however, Galileo's interest was piqued by physics. He observed the swinging of a lamp and noticed that each swing took the same amount of time. Galileo became the first person to realise this law of the pendulum, and he began to devote more time to mathematics.

At this time, Aristotle's assertion that heavier objects fell faster than lighter objects was being challenged. Legend has it that Galileo climbed to the top of the Tower of Pisa and dropped various balls of differing weight, showing that they all landed at the same time and thus proving Aristotle wrong. Famously, during the Apollo 15 mission in 1971, astronaut David Scott recreated the experiment on the lunar surface by dropping a hammer and feather and showing they fell at the same rate in the absence of air.

Following a string of inventions, including a compass and thermometer, Galileo became interested in a device that could make distant objects look much closer after hearing of it during a holiday to Venice in 1609. Galileo frantically went about designing his own such device, which we now know as the telescope, and eventually presented it to the senate in Venice.

His first major discovery was that the Moon was a heavily cratered and rough body rather than the smooth spheroid it had been thought to be before. In 1610 he built a more powerful telescope and discovered three of Jupiter's four largest moons, which are now known as the Galilean moons in his honour. Galileo also discovered the rings of Saturn, sunspots and the rotation of Venus. The discovery of the Galilean moons was the most revolutionary because it meant that there were objects in the sky not moving around Earth, but rather around other objects. Galileo's discovery added considerable weight to the Copernican idea that the Sun, rather than Earth, was at the centre of the Solar System.

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Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Content Director **Gemma Lavender**
gemma.lavender@futurenet.com
Art Editor **Jonathan Wells**
Production Editor **Nikole Robinson**
Senior Art Editor **Duncan Crook**

Contributors
Stuart Atkinson, Jamie Carter, David Crookes, Peter Grego, Andrew Jones, Robert Lea, Russell Lewin, Tereza Pultrova, Giles Sparrow, Dave Stephenson, Brett Tingley, Luis Villazon, Stefanie Waldek, Steve Wright

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Advertising
Media packs are available on request
UK Commercial Director **Clare Dove**
clare.dove@futurenet.com
Advertising Manager **Matthew Johnson**
matthew.johnston@futurenet.com
07974 408 083
Account Manager **Garry Brookes**
garry.brookes@futurenet.com
0330 390 6637

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Managing Director **Sarah Rafati Howard**
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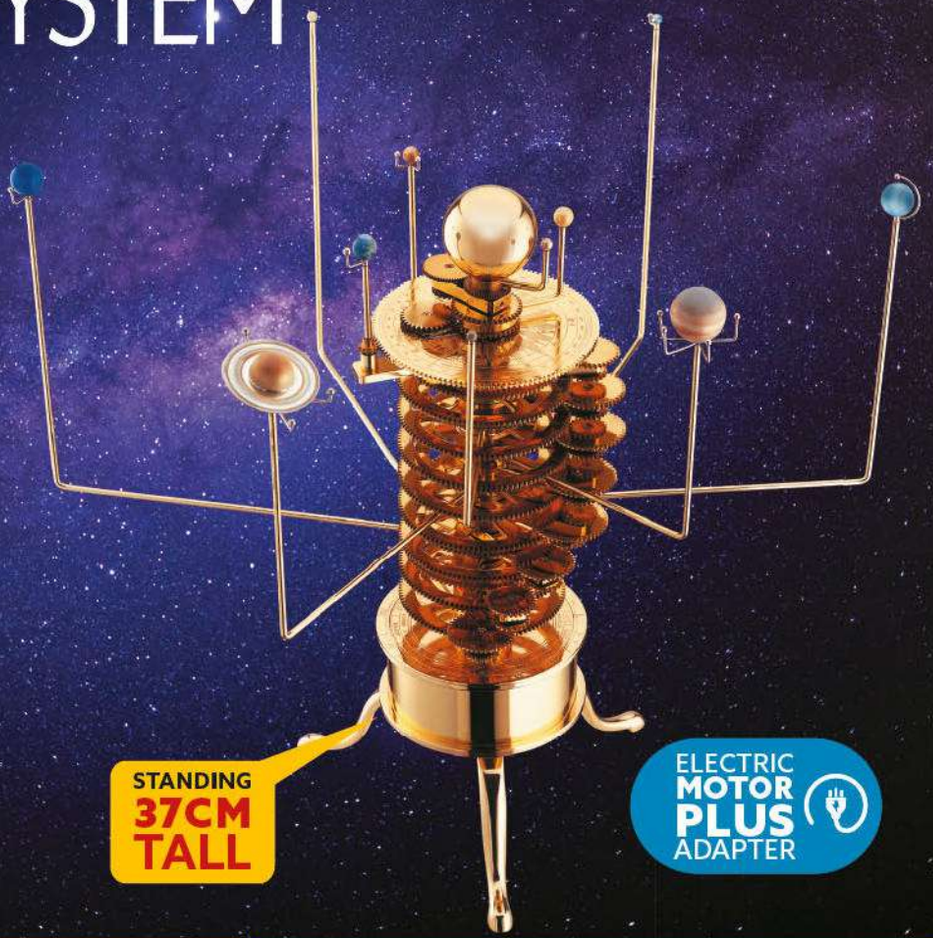

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